RAPID TRANSPORT
OF
PERSONNEL AND MATERIALS
IN
UNDERGROUND COAL MINES

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EXECUTIVE SUMMARY

The Canada Centre for Mineral and Energy Technology has a continuing interest in developing and improving mining systems to increase the productivity of the mining industry by communicating research to industry.

This study addresses transport of personnel and material in underground mines. Efficient mine transportation systems are critical to the continued economic performance of Canadian coal mines.

The study is relevant both to existing and proposed Canadian underground coal mines. The objective is to research, review, summarize and evaluate present worldwide practice, concepts, systems and equipment. The findings are presented as a "designers handbook" for rapid and efficient personnel and material transport in underground mines. Urban transit and industrial transport systems were reviewed to assess their applicability to mining. Existing and developing systems have been considered and the report addresses gradients, safety, speed, cost and reliability.

The study is not site specific and provides summary data that can be used as the basis for designing safe and cost effective mine transport systems for existing or proposed mining projects.

Transportation systems have been grouped into five categories:

- Rail Vehicles Internal Powered (RVIP)
- Rail Vehicles External Powered (RVXP)
- Free Steered Vehicles (FSV)
- Conveyors
- Miscellaneous Transportation Systems

Subgroups are then defined on the basis of type, size, capacity and power source.

Information for the study was acquired from published articles and from equipment manufacturers. A very large range of equipment is available from many manufacturers providing a wide choice of sizes, shapes and special features in almost all categories. This diversity serves the mining industry's need for machines to work in specific and often unique environments.

A general review of the transportation systems in many mines identified that there is an increasing need for long distance, rapid, underground movement of men and materials. Many presently operating systems tend to lack the speed, reliability and safety which the industry will demand in the future. Efficiency, both in terms of the number of operators required and the number and speed of transfers from one part of a system to another will be of great importance in the design of the next generation of transport systems. The pace of change in the industry is slow and mine designers tend to emphasize proven performance when specifying new equipment.

Major innovations in underground mine transport are likely to occur as a result of the application of technology originally developed for other purposes. Use of rubber tired, free steered vehicles in underground mines is relatively recent and marks the latest major change in transport systems. Technology which is now in use in urban transit systems, materials handling and specialized applications in other industries may be expected to contribute to the next major change. Rack and pinion or rubber tired locomotives, linear induction motors, guided rail steering and levitation systems are some of these emerging technologies.

Automation of control systems and materials handling are areas where improvements in efficiency and safety can be achieved. Often these improvements can be retrofitted to existing equipment with substantial benefits and acceptable costs. Micro-processor control systems offer substantial advantages in terms of ease of operation and optimization of control.

Underground coal mining presents the most challenging demand for high speed transportation of men and materials. The geometry of the coal measures in Alberta, British Columbia and Nova Scotia, the areas where most future underground production will probably originate, will require long underground hauls, sometimes at significant and changing gradients. The length of haul will inevitably increase with time as easier coal is mined out and operations progress to deeper and more inaccessible areas. This factor is particularly critical in the submarine mines of the Cape Breton Coalfield.

The report includes a detailed review of each equipment category, presentation of typical specifications and an evaluation of the applicability of each category within an overall transportation system. The most significant constraint on the selection of equipment is identified as the gradient at which it can operate safely and efficiently. There is a substantial overlap in equipment gradeability. For short distances and occasional travel this allows choice in selecting an appropriate system. Rapid long distance travel requires high speeds over sustained times and thus tends to favour captive systems over free steered systems. Main transportation routes in mines generally have the same life span as the mine itself and therefore warrant major capital expenditures to achieve long term efficiency in operation.

The report includes more than 60 data sheets on transport systems and identifies locations at which equipment is currently in use.

SOMMAIRE

Le centre canadien de la technologie des minéraux et de l'énergie est continuellement intéressé dans le développement et le perfectionnement des méthodes d'exploitation dans le but d'augmenter la productivité de l'industrie minière. Il sert de liaison entre la recherche et l'industrie.

La présente étude a pour tâche d'examiner la situation du transport du personnel et du matériel dans les mines souterraines. Pour que les mines canadiennes maintiennent leur rendement économique, il est nécessaire qu'elles soient pourvues de moyens de transport efficaces.

Cette présente étude s'applique aux mines de charbon souterraines canadiennes actuelles et à celles présentement sous considération. Le but de cette étude est de rechercher, réviser, récapituler et évaluer les méthodes, les concepts, les systèmes et les équipements actuels et universels. Les résultats de ces recherches sont publiés dans un "manuel des planificateurs", ou un résumé de l'information sur le transport rapide et efficace du personnel et du matériel dans les mines souterraines. Les systèmes urbains de transport en commun et les systèmes en usage dans l'industrie y sont passés en revue afin de juger s'ils sont appropriés à l'industrie minière. Les systèmes actuels et ceux en voie de developpement y sont étudiés ainsi que les pentes, les mesures de sécurité, la vitesse, le coût et la viabilité des machines.

Cette étude n'est pas faite pour une mine en particulier. Elle contient plutôt d'un sommaire de données qui peuvent servir de fondement à une planification des moyens de transport sûrs et économiquement appropriés aux mines actuelles ou aux projets de mine présentement sous considération.

Les éléments à considérer dans un système de transport ont été groupés en cinq catégories:

- Moyens de transport au sol sur rail à force motrice interne
- Moyens de transport au sol sur rail à force motrice externe
- Engins sur pneus
- Convoyeurs
- Autres véhicules

Des subdivisions sont alors établies à partir du type de rail, l'emplacement du rail, sa longueur et sa capacité.

L'information pour cette étude a été obtenue de différentes publications et des fabricants d'équipement. Une très grande variété d'équipement existe dans presque toutes les catégories ainsi qu'une grande sélection de grandeurs, formes et particularités. Cette grande diversité répond au besoin de l'industrie minière d'avoir des machines qui travaillent dans un milieu spécifique et souvent unique.

Une revue générale des systèmes de transport dans plusieurs mines démonstrent qu'il y a un besoin croissant pour un flux rapide de matériel et de personnel sous terre et cela sur une grande distance. Plusieurs systèmes présentement en marche n'ont pas la vitesse, la viabilité et les dispositifs de sécurité que l'industrie va exiger dans l'avenir. Dans la planification des phases à venir des moyens de transport, l'efficacité sera très importante, et ce, en ce qui a trait au nombre de conducteurs nécessaire aussi bien qu'à la quantité et à la vitesse des transferts d'une partie à une autre du chantier. Le changement se produit lentement dans l'industrie et les dessinateurs de mine ont tendance à s'appuyer sur des rendements bien établis quand ils recommendent de l'équipement neuf.

Il est probable que des perfectionnements considérables se produiront dans les moyens de transport souterrains par suite de la mise en oeuvre d'une technologie originellement développée pour d'autres usages. L'emploi d'engins sur pneus dans les mines souterraines est relativement nouveau et représente le plus récent changement majeur dans les moyens de transport. On peut s'attendre que la technologie qui est présentement employée dans les systèmes urbains de transport en commun, dans la manutention et dans les réalisations spécialisés contribuent aux prochains changements. Un chemin de fer à crémaillère ou des engins sur pneus, des moteurs linéaires, un monorail à câble guidé et un monorail avec locos suspendues sont quelques exemples de la technologie d'avant-garde.

Des améliorations dans l'efficacité et la sécurité pourraient être étudiées en ce qui a trait à l'automatisation des moyens de transport et de la manutention. Souvent ces améliorations peuvent être adaptées à l'équipement existant avec de bons résultats et à des coûts raisonnables. Des moyens de contrôle par micro-ordinateurs facilitent grandement l'opération de la mine ainsi qu'un contrôle optimal.

Le transport rapide du personnel et du matériel dans les exploitations souterraines de charbon représente un très grand défi. La géométrie des chantiers en Nouvelle-Ecosse et en Alberta, les deux régions où se fera la plus grande partie de la production souterraine future, nécessitera de longs parcours souterrains avec quelquefois des voies plus ou moins inclinées. La longueur des parcours changera inévitablement à la longue à mesure que le charbon plus facile d'accès est exploité et que l'abattage arrivera à des régions plus profondes et plus difficiles à atteindre.

Cette étude comprend une revue détaillée de chaque catégorie d'équipement, une description précise des spécifications et une évaluation de la mise en oeuvre de chaque catégorie à l'intérieur d'un même moyen de transport; La constrainte la plus importe est la disparité des pentes sur lesquelles l'équipement devra opérer d'une manière sûre et efficace. Plusieurs de ces machines ont une capacité similaire quant à leur aptitude à fonctionner dans les pentes. Le choix de l'équipement est plus facile pour les parcours de courte distance et le déplacement occasionnel. Pour le transport rapide sur une grande distance, il est nécessaire de choisir un équipement qui peur fonctionner à grande vitesse pendant des périodes éprouvées. Cela favorise les moyens de transport sur rail à guidage captif plutôt que les engins sur pneus. Les voies principales de transport dans les mines durent en général aussi longtemps que la mine elle-même. Par conséquent, il est justifiable d'y investir une importante part du capital afin d'assurer une efficacité à long terme.

Ce rapport comprend aussi plus de 60 feuilles de données sur les moyens de transport et il indique l'équipement le plus couramment en usage.

SECTION 1

INTRODUCTION

1.1 SCOPE OF WORK

This review is based on published information and data available in the public domain. The following items identify the scope of work:

1. Summarize developed concepts, approaches, techniques and technologies which are being used as efficient underground rapid transport systems for personnel and materials in coal mines. This summary should address:

    a) transport vehicles and systems to be used on grades up to 15°
    b) roadbed requirements and speed limits
    c) mechanized, automated and modular material handling, transporting and storing techniques for surface, underground transfer points and end of line
    d) control systems, communciations, interactive on-board status monitoring, central dispatch, application of emerging micro processor technology
    e) transport modules for personnel and materials
    f) safety devices and safety of personnel in case of emergencies e.g. a mine fire or cave in
    g) capital, operating, maintenance and replacement costs
    h) system reliability

2. Discuss the strengths and weaknesses of each system considered under item (1) above. Analysis of systems must be in sufficient detail projecting the maximum attainable level of performance of each system. A ranking matrix will be developed incorporating each system evaluated.

Modifications required in the top three systems to achieve the maximum performance compatible with proposed mine development will be identified and discussed particularly with reference to the cost and time frame involved.

3. The proposed contract is not limited to technology developed for the coal mining industry. Developments in other fields (metalliferous mining, urban transit, heavy industry, etc.) should be surveyed. The applicability and incorporation of such developments to existng and proposed to be modified underground coal mine transportation systems, to improve efficiency, should be evaluated.

4. Site visits to operating underground coal mines and centres of related expertise will be considered only with the prior written approval of Scientific Authority.

This Scope of Work was revised by letter agreement dated October 16, 1984 as follows:

- The main thrust of the study is to prepare a designer's handbook for personnel and materials transport in underground coal mines, covering developed techniques.
- Each candidate technique will be summarized and reference will be made to the factors listed in items a-h of the Work Statement.
- Where practicable capital and operating costs and performance potential will be addressed.
- Techniques will be classified in categories of application as follows:
    - Main accesses, inclined up to 25% (15°)
    - Long horizon tunnels

  - In-seam dips ($0-5^{\circ}$, $6^{\circ}-15^{\circ}$, $+15^{\circ}$)
  - In-seam strike roadways

- The study will not be site specific and will be relevant to any Canadian underground coal mine.

- No quantitative ranking will be undertaken.

- Techniques from non-coal applications will be considered where appropriate.

A final revision to the intent and scope of the study was made by letter agreement dated November 7, 1984 as follows:

- In addition to the work elements addressed in my letter to you of October 16th, 1984, we will identify "case histories" or examples of operating systems.

1.2 METHODOLOGY

Transport equipment for personnel and materials has been categorized as follows:

a) Rail vehicles internal powered (RVIP)
b) Rail vehicles external powered (RVXP)
c) Free steered vehicles (FSV)
d) Conveyors
e) Miscellaneous transportation systems

Rail vehicles, both internal and external powered, are classified as either non-trapped or trapped, and can be roof or floor mounted. They are then subdivided into size categories of small, medium or large by either man capacity, load capacity or power.

Free Steered Vehicles (FSV) are divided into small, medium and large and are identified by a common name - tractor, truck, bus etc. As there are a large number of FSV's available they are further subdivided by power source and steering method. Only rubber tired FSV's are included in this study.

Conveyors are always constructed site specific and are made up of equipment from a large number of manufacturers of drives, controls, components and belting. Conveyors are categorized by belt construction, riding configurations, component designs and length of run. Chain conveyors have been mentioned as they are sometimes used for equipment transport in face areas.

A large number of equipment manufacturers and suppliers were contacted in Australia, Canada, Czechoslovakia, France, Poland, Romania, Sweden, U.K., U.S.A., U.S.S.R. and West Germany. Representative equipment from a wide variety of sources is described in the study.

Omission or inclusion of descriptions of particular equipment should not be considered as a recommendation for or against any equipment manufacturer or supplier. Some equipment included is only used in metal mining. Some equipment used in industry is included, but is not currently used in coal or metal mining. In some instances, where no clear cut designation is possible, an arbitrary classification has been made.

Where available, 1984 FOB factory costs have been provided in Canadian dollars for selected equipment. Typical examples of use in Canada and other countries are identified.

Emphasis has been placed on Canadian certified equipment if available. In some cases equipment certified in the country of origin has been described. It should be noted that the Canadian Government is presently involved in a review of certification standards and procedures. This review is extensive and involves U.K. and U.S. manufacturers and governmental agencies.

Articles or papers published before 1970 were generally excluded from the research and data acquisition carried out during the study.

SECTION 2

PERSONNEL AND MATERIALS TRANSPORT

2.1 BACKGROUND

This study has been prepared as a result of a request for proposal (RFP) from the Minister of Supply and Services Canada titled "Rapid Transport of Personnel and Materials in Underground Coal Mines" dated July 10, 1984.

The RFP reflects a genuine concern regarding the present and future status of underground coal mining in Canada. Literally billions of tonnes of Western and Eastern Canadian coal is available for mining by underground methods if mine mouth costs can be reduced substantially.

One method of reducing the costs of producing coal is to improve the logistics of mining operations, including transportation systems. Transportation may be improved by reducing the time it takes to transport personnel to the production area, increasing the reliability or availability of the system being used to transport personnel, reducing the number of personnel needed to operate the transportation and supply haulage system, reducing the overall maintenance required to operate a high quality mine transportation network and reducing lost production associated with transport systems. While doing this a safe transportation system must be maintained for the personnel operating and utilizing the equipment.

Various systems are used to transport men and materials in underground coal mines including man-trains, supply trains, slope hoists, conveyor belts and free steered rubber-tired vehicles. It is common for a miner to spend some 20 percent of his eight hour working shift travelling from the surface to his work area and returning to surface. Up to 10-20% of the total work force are normally involved in the movement of personnel and supplies. A significant percentage of lost time accidents and fatalities are directly attributable to the transportation of men and supplies.

Each mine is unique in the type and performance of its transportation but most systems typically consist of four elements:

- transportation of men and materials from the surface dry/lamp area to the surface mine opening
- transportation from the surface mine opening to the end of the main transport system often at the coal seam elevation
- transportation from the end of the main transport system to a staging area near the working face
- transportation from the staging area to the working face

2.2 HISTORICAL DEVELOPMENT

Little was known of the earliest systems of transport of personnel and materials in mines before Georgius Agricola published De Re Metallica in 1556. In 1617 John Taylor records that the tunnels under the Firth of Forth were "artificially cut like a vault ... that a man may walk upright ... both in and out".

While the mechanical principles of the block and pulley, windlass, shafts, gears and wheels were all known to the ancients, manpower, water power, and animal power were the only prime movers available until the eighteenth century. Indeed animal power was common in coal mines up to World War II, long after the initial introduction of steam power.

Conveyances of personnel and materials first became mechanized in vertical and steeply inclined shafts with the introduction of reciprocating beam engines which were known as man engines. They were first used in Cornwall, England. Mechanization of transport in horizontal and shallow incline workings occured later with the installation of rope haulage systems utilizing steam hoists. With the availability of compressors, compressed air locomotives were developed. Electric trolley locomotives were first introduced underground before the turn of the century and are still used extensively in the U.S.A. and the U.S.S.R. In the 1930's with the introduction of high speed diesel engines and improved batteries both diesel and battery locomotives became available. In the 1960's the high speed, high powered conveyor belt was introduced originally for mineral transport and subsequently for personnel and materials transport.

The last twenty years has seen the increasing use of free steered vehicles (FSV). Commonly, these are diesel powered four wheel drive vehicles with articulated steering.

In the United Kingdom and Eastern Canada, the nature of the coal deposits and the long travel distances involved have required development of transport systems for personnel and materials which tend toward shaft/slope rope haulage systems (Figure 2) and belt conveyor systems supplemented by battery or diesel locomotives.

This is in sharp contrast to Eastern U.S. coal fields which are characterized by flat lying seams with generally competent roof where multi-entry development and conventional rail trolley locomotives are common for transport of coal, personnel and materials. Battery powered FSV's are used extensively for supplementary transport, clean up and utility service. Belt conveyors are also common for coal transport. State mining regulations and concern for worker safety presently inhibit the widespread use of diesel engines in underground coal mines in the Eastern U.S.A. Rope haulage and monorail systems are rare and trapped rail is not used.

The coal fields of Western Canada and Western United States are characterized by relatively thick sometimes steeply dipping coal seams. In the past these were developed by centrally located, in-seam slopes equipped with hoist rail systems. Recently rubber tired diesel powered FSV's have been introduced for development, mining and transport of personnel and materials.

European coal mines have developed along rather different lines because of the nature and depth of the coal deposits and the variable floor conditions. Coal seams are frequently entered by massive relatively permanent vertical shaft systems and elaborate trapped rail or monorail systems are common for the transport of coal, personnel, materials and equipment.

2.3 CURRENT NEEDS

Each underground coal mine is unique and problems in transporting men and materials vary considerably from mine to mine. In many collieries, the transport system is comprised of a number of interacting sub-systems which accommodate varying dip of the seam, changing distances as the mine workings move, the severity of conditions and earlier installations. These systems must transport large numbers of people to and from the working face, must handle supervision, maintenance, engineering personnel and visitors. Materials, equipment and supplies of different shapes, weight, dimensions, quantities, time requirements and points of use must be delivered in good usable condition and in many cases must be salvaged and moved to a new workplace several times.

Evaluation of typical personnel and materials transportation systems in many mines yields the following general observations:

- Mines are generally getting deeper and are mining more difficult coal at greater cost.
- Transportation systems differ greatly from mine to mine.
- Priority is given to face production and transport of coal.
- Transport of men and materials is frequently hindered by poor system availability.
- Hazards, delays and transfers are built into the system.

- Transport accidents are common with little or no improvement in lost time accidents or fatalities in recent years.
- Transport of men and materials is costly and frequently labour intensive.
- Some of the loading and much of the unloading of materials and supplies is done by hand and there is a great deal of rehandling, loss and damage before they reach their point of use.
- Material and supply trips are usually on the day shift. Low priority and poor planning can lead to shortages or emergency requirements which often disrupt normal transport.
- Emergencies due to accidents cause serious disruptions to transport schedules or systems.

Current needs are to:

- eliminate walking long distances
- eliminate or reduce transfers of men and materials from sub-system to sub-system
- increase speeds to reduce overall travel time
- increase safety and health
- eliminate delays
- reduce operating and maintenance costs
- reduce number of personnel employed in transport
- transport large numbers of people
- operate in severe gradients, changing gradients, explosive atmospheres, dust and humidity
- accommodate long distances and changes in distances
- be reliable, easy to install, operate and maintain
- deliver a variety of materials at varying time requirements and points of use, eliminate waste and degradation
- operate in emergency conditions
- be environmentally acceptable
- be easily automated or operated by remote control

2.4 EXISTING TECHNOLOGY

The components of transportation systems for men and materials and other minerals or combinations of duties which are in use around the world today may be categorized by type and power source. For the purpose of this report a classification has been developed based on four principal categories, as follows:

Rail Vehicles Internal Powered (RVIP)

Rail Type:	Non-trapped
	Trapped
Rail Position:	Floor
	Roof (monorail)
Power Source:	Diesel engine
	Battery electric
	Trolley electric
	Trailing cable electric
	Combination power sources

Rail Vehicles External Powered (RVXP)

Rail Type:	Non-trapped
	Trapped
Rail Position:	Floor
	Roof (monorail)
Rope Configuration:	Single drum
	Double drum
	Endless rope
	Main and tail rope
Power Source:	Electric motor
	Diesel engine

Free Steered Vehicles (FSV)

Size:	Small (e.g. supervisors truck)
	Medium (e.g. 10 man conveyance)
	Large (e.g. +30 man conveyance)
Power Source:	Diesel engine
	Battery electric
	Trolley electric
	Cable reel electric
	Combination
Steering System:	Conventional wheel steering
	Four wheel steering
	Articulated steering

Tracked vehicles have been excluded from this study since they are not appropriate for rapid transport of men or materials.

Conveyors

Type:	Common belt (fabric or steel cord)
	Cable belt
Power Source:	Electric

Armoured face conveyors are excluded from this study since they are not appropriate for rapid transport of men or materials. They may, however, be used for movement of equipment at the face in the last stage of a transportation system.

In addition to the four principal categories above, other categories are discussed that embrace additional transportation components. These include Miscellaneous Transportation Systems, Ancilliary Transportation Systems and Monitoring and Control.

One or a combination of several transportation system components may form part of the overall transport network in a mine. In large collieries several independent systems may exist to serve different areas of the mine and to provide manriding and materials handling facilities separate from the mineral handling system.

Equipment for use in mines, especially coal mines, is subject to approval from regulatory agencies. In many instances approval is granted only after detailed inspection of the equipment and testing in government facilities. This process takes time and contributes to the slow pace of change and innovation in mining equipment. Once equipment and systems are installed in a mine the potential benefits of changes or improvements are often secondary to the demand for proven performance. The industry as a whole is very capital intensive and there is an inherent economic requirement to use installed equipment for as long as possible before replacement. This leads in some cases to a "run it into the ground" philosophy where the economic life of equipment is exceeded and operating costs begin to rise.

These factors tend to reinforce the choice of proven equipment for new mines and together with the long life span of mining installations contribute to the slowly changing nature of transportation installations and equipment. Recent developments in equipment for rapid transport of men and materials have largely been in the area of free steered vehicles and in the evolution of improved engine and battery performance for internal powered vehicles. FSV's are the only totally innovative addition to the range of equipment available in the last 50 years. All other changes have been the result of modifications of older systems.

The increasing cost of manpower and fuel, coupled with deeper mining at greater distances from mine entries all impact on existing transportation systems. Original systems installed at the beginning of a mine's life, and then extended to reach the furthest limits of mining are the systems which experience the heaviest and longest use. They are often labour intensive to operate and maintain, inefficient for the duty they must perform and tend to operate at slower speeds than the initial design.

While most basic transportation systems in use today are the same as those installed in mines since the turn of the century, some components of the systems have undergone considerable evolution. Changes in electrical control systems and the trend towards self-propelled units using diesel power are the most notable improvements. Modernization tends to be limited to those components which are retired at the end of their useful life.

Existing systems which provide high speed transport for men and materials are invariably those systems which have been specifically designed, installed and maintained to provide efficient service. The components of most existing systems could be considered fairly high speed devices, the systems overall, however, are seldom nearly as fast as their individual parts. Transfer from one component of the system to another and possibly to a third takes time and uses manpower. Proper organization of transfers is vital to system performance and is frequently the major impediment to rapid transport in existing mines.

Technological innovation in materials handling and transport which has occurred in industry generally is beginning to be used in mining. Some areas which have applicability include:

- Palletization and containerization of material
- Specialized pallet and container handling equipment
- Energy absorbing arrestors
- Encapsulated manriding
- Automation and computer control of movements on the system
- Welded rail, ATC rail and trapped rail.

More recent developments are discussed in the following section.

2.5 EMERGING TECHNOLOGY

Transportation systems and components which are currently being tested in underground mines or which are being developed or used only for surface applications (Appendix A) are classified as emerging technologies when some major innovation is included in their design or application. The items listed are those which are believed to be suitable for underground rapid transport applications.

Non-trapped Rail Vehicles

Electric Powered - Conventional Motors. This type of unit is used extensively for surface applications. The vehicles have steel wheels and run on conventional steel rails. Propulsion is generally with DC electric motors and power is supplied from either an overhead trolley line or a third rail. Systems employing these units are capable of high speed and high capacity but have limited gradeability. Examples of systems in use for city rail transit:

- trolley street car (Toronto CLRV)
- trolley subway (Calgary and Edmonton LRT)
- third rail subway (Toronto subway)

Diesel Powered - Steel Wheel. Examples of this type are in widespread use for surface transportation. They are generally of large cross-section, high horsepower with multiple power units. They operate at high speed with low maintenance, high reliability with extremely high capacity. They are limited to approximately 5^o grade for short distances but should be designed with maximum gradients of less than 1^o.

A high speed tandem diesel locomotive installed at Easington Colliery in 1973 is capable of transporting 168 men at 40 km/h, a total distance of 10 km one way.

Trapped Rail Vehicles

Diesel - Rubber Adhesion/Rack and Pinion. Rack and pinion locomotives are in widespread use around the world for high speed, high gradient operation. Examples of use can be found in Switzerland, Washington, and in Britain.

Hunslett has a locomotive with rubber tired adhesion combined with rack and pinion drive unit under development. This unit is capable of operating in adhesion drive up to 4° maximum. In steep grade areas it can operate in rack drive up to 10° maximum.

Battery - Rubber Adhesion. Gyro Mining Transport is developing a self propelled train with rubber tired adhesion drive units throughout the length of the train. These units are capable of high speed up to 7° gradient. A test vehicle is at Shirebrook Colliery, UK.

Free Steered Vehicles

Rubber Tired Electric Trolley - Free Steered. These trolley bus vehicles give high performance with good reliability and low maintenance. Examples are found in Toronto, Vancouver, Edmonton and San Francisco.

Kiruna has recently developed a new low profile articulated electric powered truck specifically for transport on inclined roadways in mines. The power supply is a contact rail specifically designed for mine conditions. This vehicle can carry a payload of 50 tonnes up a 10° grade at 50 km/h. Eimco has developed a trolley track system to eliminate trailing cables from electric powered mining vehicles. Overhead conductors are suspended from a rail on which the trolley pickup runs. The trolley, loosely attached to the vehicle, follows forward or backwards automatically. Eimco has also developed a cable hanger system to extend the cable reel range of travel. This system has a large stationary ground mounted cable reel with its own hydraulic power unit integrated with an overhead rail fitted with cable hangers. A cable threader automatically hooks the cable through the hangers as the machine advances or retreats.

Rubber Tired Diesel - Free Steered. This system is widely used in all forms of transport. Of special interest is the Arion II bus which has a lower profile. It is of robust stainless steel construction with four wheel drive.

The superbus (Appendix A) is a tractor trailer combination utilizing standard free steered tractors pulling one or more trailers. These demonstration units are capable of speeds up to 90 km/hr and can operate up to 14° grade.

Guided Rail Steering. This system is well developed and can be automated. Westinghouse has installed them at Miami and Tampa airports. The Montreal metro is also an example of this system.

Electronic Steering is at the experimental stage and requires further development.

Innovative Propulsion and Friction Reducing Systems

Linear Induction Motors (LIM)

The linear motor may be described as a squirrel cage motor opened up and flattened out to form a long strip (the stator) against which the armature moves in a parallel direction.

On Board LIM. In this system the primary coils are located on board the vehicle and the secondary is located at wayside usually between the tracks. An example is the Wedway, operating at Houston International Airport. Other examples are under construction at Vancouver and Scarborough.

These systems are capable of high speed, high reliability and low maintenance, but have limited gradeability and require close air gap tolerances.

Wayside LIM. One system is operational at Gardanne Colliery in France where a rolling corridor 2.5 km in length is utilized for the transport of coal. It has a maximum velocity of 25 km/hr with a capacity of 670 t/h. The corridor consists of 1.5 m long sections which carry a reaction plate and support a length of troughing. The troughing sections are connected together to form a continuous trough or corridor which carries the coal. The corridor is propelled by induction coils placed at intervals between the tracks.

It has not as yet been used for personnel transport. Theoretically, steep grades could be negotiated as dependence on rail adhesion is eliminated.

Magnetic Levitation

There are three categories of magnetic levitation systems - electromagnets, super conducting magnets and permanent magnets.

Electromagnet systems are experimental and require further development. Super conducting magnet systems theoretically require very little power to operate but have serious problems supercooling the magnet and are only experimental. An example of the use of the permanent magnet system is under construction in West Berlin, designed to use LIM for propulsion.

Air Levitation

Air Cushion Vehicles use large volumes of air at relatively low pressure and lift the vehicle a substantial distance off the track or roadway. This allows the vehicle to operate over severe terrain or water, e.g. Hovercraft.

Air Bearing Vehicles use a thin film of air for lift and require a smooth surface. An example is the Otis Hovair installation in North Carolina which can transport 29 people at speeds up to 30 km/hr.

The Vacuum Lift system uses a vacuum monorail system and has the manriding vehicle suspended below. This system is presently experimental.

Other Emerging Developments

Development in the United Kingdom is being conducted on sodium-sulphur batteries which could theoretically provide four times the storage capacity of a lead-acid battery of the same weight and which would not emit any dangerous gases. The Bureau of Mines in the United States is evaluating a design for a high performance iron-nickel battery and charger system for suitability in underground battery scooptrams. Other battery types are under investigation.

Other power developments include:

- Flywheel power
- The Stirling Engine
- Steam Engines
- Liquid Nitrogen Fueled Engines
- Hydrogen Hydride Fueled Engines
- Compressed Air Power
- Gas Turbines
- Diesels
- Adiabatic Engines
- Water Soluble Fuel Oil
- Ceramic Exhaust Filters
- Self Regeneration Exhaust Catalyst Traps
- Venturi Exhaust Control
- Electronic - fuel injection

  - diagnosis
  - monitoring and control
- Turbocharging and supercharging
- Advanced cooling systems

Other developments include:

- Automatic Guidance Systems
- Fail Safe Brakegear for High Speed Manriding Locomotives
- Accelerating and Decelerating Systems for High Speed Manriding Conveyor Belts

Pedestrian Movers

There are a number of pedestrian movers utilized in surface transport of personnel. Walking belts and escalators are typical examples. These systems while fairly common are expensive, slow and limited as to length.

Conclusions

The present trend of adapting surface industrial proven equipment for use in underground mining is expected to continue at an accelerating rate. Some of the emerging systems presently under construction or development for urban transit and heavy industrial use will almost certainly find future applications in underground coal mining.

SECTION 3

CANADIAN UNDERGROUND COAL MINES

3.1 GENERAL

Coal deposits are widely distributed in Canada (Figure 3-1) and there is a great diversity in age, rank, quality and in the geographical and geological conditions in which they occur.

Until 1950 the major demand for coal was for steam locomotives and domestic heating with a minor demand for coking coal for blast furnaces and foundries. Supply was from relatively small underground producers utilizing simple methods and equipment. With the advent of diesel locomotives, oil heating and natural gas availability, demand for coal decreased rapidly and the industry entered a period of decline.

After 1970, the emerging export market for metallurgical coking coal and thermal coal encouraged the opening of a number of large scale surface mines and underground room and pillar, hydraulic and longwall mines.

NEWFOUNDLAND, NOVA SCOTIA, NEW BRUNSWICK AND QUEBEC

There are 11 known coalfields in Nova Scotia (Figure 3-2) most of which have been extensively mined. The most important field is the Sydney Coalfield. It contains high volatile bituminous coal which has not been greatly disturbed geologically and generally dip from 6^{o} to 15^{o} seaward. The most significant remaining reserves lie in the submarine areas. Mineable seams vary from 1 m to 2.5 m thick.

There are two coalfields in New Brunswick. Commercial production is confined to small open pit mines in the Minto Coalfield.

There is no underground coal mining activity in New Brunswick at the present time.

Very little information is available concerning the coal deposits in Newfoundland. There is no current production from surface or underground. The peat deposits in Quebec are virtually unexploited.

ONTARIO, MANITOBA AND SASKATCHEWAN

The peat and lignite deposits in Ontario and Manitoba are virtually unexploited although significant exploration work has been carried out on some deposits.

In Saskatchewan some of the lignite seams are being mined by large open cast strip mines for steam power generation (Figure 3-3).

No underground coal mines exist or are planned in these provinces.

ALBERTA

Coal bearing formations underly almost half of the province of Alberta (Figure 3-4). These coal bearing areas can be divided into three regions:

- Plains
- Foothills
- Mountain

The plains region contains large deposits of sub-bituminous coal which is generally flat lying and reasonably thick with low sulphur content. Some of these deposits are amenable to large scale mechanized longwall underground mining but there are no underground mines operating in this region at the present time. The Foothills region is characterized by high volatile bituminous coal suitable for high grade thermal use. It is low in sulphur and up to 7 m thick. The Mountain coal is low to medium volatile bituminous coal suitable for metallurgical use, it is also low in sulphur and up to 15 m thick. Both the mountain and foothills coal bearing formations lie in complex configurations showing extensive repetition of seams and local thickening or thinning associated with tectonic disturbances.

BRITISH COLUMBIA

The coal fields of British Columbia are large and numerous (Figure 3-4).

In the East Kootenay region the Crowsnest field has been extensively explored and mined. There are up to 15 seams with aggregate thickness to 60 m of low to medium volatile coal with very low sulphur content. At the present time four large open pit operations provide both thermal and metallurgical coal for the export market. Two underground mines are in operation.

The Elk River and Flathead coal fields have been extensively explored but there has been no production from these areas to date.

The Peace River deposits are continuations of the mountain, foothills and plain region coals found in Alberta. Eleven seams are found in the Gething formation and six in the Gates. The coal quality is excellent medium volatile bituminous with low sulphur content. Coal thickness is up to 9 m with flat to steep dips in synclines or anticlines highly folded and faulted. Two large open pit coal mines have recently been completed to produce thermal and metallurgical coal for the export market. No underground mines are presently planned or in operation.

Large quantities of thermal coal occur in the Hat Creek and Comox fields where exploration has been conducted. There is no present production from these fields.

YUKON AND NORTHWEST TERRITORIES

The numerous coal occurrences in the Yukon and Northwest Territories (Figure 3-5) are relatively unexplored and undeveloped except for small open pit mines for energy requirements for local plant heating. The coal occurrences in the Arctic Islands are virtually unexplored.

3.2 ACTIVE AND PROPOSED UNDERGROUND MINES

3.2.1 Alberta

There is one producing mine and several at the planning stage in Alberta (Table 3.1). The one underground producing mine is in the Grande Cache area. This is a room and pillar mine with drivages and crosscuts 5 m wide x 3 m high on 30 m centers. The roof is supported by roof bolts on 1.2 m centers, screened and with timber side supports on the high side. At the completion of development, the pillars are mined out and allowed to cave. Mining equipment consists of continuous miners, shuttle cars, belt conveyors and roof bolters.

Some development has been completed at other underground mines at Grande Cache but further development and production has been postponed pending improved market conditions.

At Cardinal River the underground mining area is a plunging syncline structure from 10 - 30 m thick amenable to hydraulic mining. The main access tunnels and coal entries have been driven but further development has been postponed.

The underground feasibility test mine at Coal Valley was closed in 1983. The company has no plans to supplement production from underground mining at the present time.

The planning and test mining of the coal deposits at Shaughnessy, Kipp and Picture Butte in the Southern Alberta Plains have been stopped. The test mine facilities have been closed. These deposits near Lethbridge may be amenable to underground mining using modern longwall methods.

3.2.2 British Columbia

There are two underground coal mines operating and one small underground mine under development in British Columbia as well as others at the planning stage (Table 3.2). The Balmer South mine is working a 17 m thick seam by hydraulic sub-level caving. The seam has an overall dip of about 38°. Main entries and sub-levels are developed in the seam using continuous miners at from 5° to 9° gradients and are supported by steel arches. Retreat mining is carried out from the sub-levels using hydraulic monitors and water flumes for coal transport. (Note: Production was stopped at the Balmer South mine early in 1985.) The Balmer North is a mechanized room and pillar underground coal mine.

The development of the Wolf Mountain underground coal mine at Nanaimo is proceeding.

The announced underground mine development project at Bowron River has been halted due to lack of funds.

The planned underground mine at Chetwynd of David Minerals is awaiting satisfactory financial arrangements.

The development at Sukunka has been placed on care and maintenance.

3.2.3 Nova Scotia

The Cape Breton Development Corporation produces the bulk of the coal mined in Nova Scotia from two submarine underground mines in Sydney coalfield. They also are developing three other underground submarine mines in the same area (Table 3.3).

The Lingan mine at New Waterford is developed in the Harbour seam by five parallel declines on 36 m centers. The initial 1700 m from surface is angled at 45° to the strike of the seam then turned and the final 2400 m driven down dip. Ground support is by steel arches. Initial production was by mechanized room and pillar in the 100 - 250 m shallow cover zone. This was followed by advancing mechanized longwalls when deeper cover was reached. Panels are advanced approximately on strike and mining is progressing down dip at increasing depth.

The Prince mine at Point Aconi is developed in the Hub seam. The initial mining was by mechanized room and pillar. Subsequently three roadways were continued down dip a distance of 2100 m then turned northward and continued a further 2000 m downward across the dip to the present mining area. Mining is by mechanized retreat longwall.

The Donkin-Morien project near Glace Bay is in the access development stage.

The Lingan-Phalen project in the Lingan mine area is under development. #1B Colliery near Glace Bay will be rehabilitated to replace lost production from #26 Colliery.

3.3 PERSONNEL AND MATERIALS TRANSPORTATION PRACTICE

3.3.1 General

The current status of personnel and materials transportation practice in Canadian underground coal mines is summarized in Table 3.4 through 3.6.

3.3.2 Alberta

At the #9B Smoky River underground room and pillar coal mine in Grande Cache, miners are transported from the mine dry to the mine portal by bus. They then either walk to their work area or are transported by a diesel powered free steered vehicle (Table 3.4). Return transport to surface is by walking, FSV's or riding the main conveyor belt to surface. The return journey to the mine dry is by bus.

Materials are manually loaded from a surface storage yard on to battery powered tractors or into the buckets of battery powered scoop trams or diesel powered LHD's for transport to the underground storage areas or work areas as required. Materials are manually loaded on to electric powered shuttle cars for transport to the working face.

3.3.3 British Columbia

At the Balmer North underground mechanized room and pillar mine men are transported from the surface to their underground work area either by walking or in manriding modules on battery powered scoop trams (Table 3.5). Materials are manually loaded into the bucket of the scoop trams for transport to the work areas and shuttle cars are used as auxiliary vehicles to transport materials to the working face.

At the Balmer South hydraulic mine diesel powered FSV personnel vehicles or LHD manriding modules were used to transport miners to the underground work areas. Materials transport was by LHD's and by diesel powered tractors.

3.3.4 Nova Scotia

At the Lingan mine there are three slope hoists installed on surface (Table 3.6). The system at #2 slope has a capacity of 180 men per trip, at #3 slope

96 men per trip and at #4 slope 120 men per trip.

At the slope bottoms or landings men transfer to either diesel locomotive floor mounted rail man-car trams or endless rope floor mounted rail, man-car trains in which they are transported to their working area.

Material is loaded at the surface on material cars, lowered to the staging area with the slope hoist system and is then transported to the required working area by endless haulage system and conveyor belt; endless haulage system and tugger hoist; tugger hoist or conveyor belt.

At the Prince Mine one slope hoist on surface is used to lower 208 man rail car strings down #4 slope approximately 2700 m to the turn where the cars are transferred to an endless rope haulage system to travel a further 2000 m down #5 slope to a staging area. From this point men are either transported by endless rope, rail, man-cars or walk to their working areas.

A new high speed endless haulage system is being installed and will operate in #2 slope to the turn and continue down #3 slope to the bottom of the mine. This system will have capacity for 208 men.

The personnel and materials transportation systems for the development projects at Donkin-Morien, Lingan-Phalen and #1B are in the planning stage.

At the underground conventional room and pillar Saint Rose mine a slope hoist is used to hoist coal in floor mounted rail type coal cars. An endless rope haulage system transports the coal cars from the mining areas to the slope. Personnel and materials are transported in these coal cars.

3.4 FUTURE REQUIREMENTS

Underground coal mine operations will be under intense cost pressure in the marketplace in the next decade. To be competitive, existing Canadian underground coal mines and the new mines which will be opening up, must demonstrate high productivity, low operating costs and a high level of safety in the workplace. The transportation of men and materials in underground mines is a major and critical component of mining operations in which substantial performance improvement can be achieved by planning and designing for efficiency and utilization of innovative systems.

One of the ways to increase efficiency is to improve availability of existing systems through improvements in maintenance and operation procedures. In future increased transport efficiency will be attained mainly be the installation and use of more powerful and higher speed systems. These systems will be capable of operating in severe conditions of gradient with improved reliability, maintainability and safety. Walking and transfers will be eliminated. Modular containers for personnel and materials will be utilized. Remote control and automation of systems will be attained through the use of advanced micro-processing equipment.

TABLE 3.1

UNDERGROUND COAL MINES
IN
ALBERTA

Operator	Location	Name of Mine	Status
Cardinal River Coals Ltd.	Hinton	Luscar	Development suspended
Luscar Sterco (1977) Ltd.	Edson	Coal Valley	Development suspended
Petro-Canada Explorations Inc.	Lethbridge	Kipp	Development suspended
Smoky River Coal Ltd.	Grande Cache	#9B	Producing
		#9G	Under development
Precambrian Shield Resources Ltd.	Lethbridge	Picture Butte	Feasibility study
Fording Coal Ltd.	Lethbridge	Shaughnessy	Feasibility study

TABLE 3.2

UNDERGROUND COAL MINES
IN
BRITISH COLUMBIA

Operator	Location	Name of Mine	Status
Westar Mining Ltd.	Sparwood	Balmer North	Producing
		Balmer South	Development suspended
Norco Resources Ltd.	Prince George	Bowron	Planning development
David Coal Corp.	Chetwynd	Willow Creek	Planning development
B.P. Canada Limited	Chetwynd	Sukunka	Development suspended
Netherlands Pacific Mining Co.	Nanaimo	Nanaimo	Developing

TABLE 3.3

UNDERGROUND COAL MINES
IN
NOVA SCOTIA

Operator	Location	Name of Mine	Status
Cape Breton Development Corp.	New Waterford	Lingan	Producing
Cape Breton Development Corp.	Point Aconi	Prince	Producing
Cape Breton Development Corp.	Glace Bay	Donkin-Morien	Developing
Cape Breton Development Corp.	New Waterford	Lingan-Phalen	Developing
Cape Breton Development Corp.	Glace Bay	No. 1-B	Rehabilitation
Evans Coal Mines Limited	Inverness	St. Rose	Producing
Pentum Mining and Exploration	Springhill	Rodney	Underground testing
Suncor Inc.	Stellarton	Acadia	Planning

TABLE 3.4

ALBERTA UNDERGROUND COAL MINES
PERSONNEL AND MATERIALS TRANSPORTATION

Name of Mine	Mining Method	Personnel Transport	Material Transport
Luscar	Hydraulic	(inclined rope haulage using man cars) RVXP	(inclined rope haulage using man cars) RVXP LHD (EIMCO)
Coal Valley	Under development	Walk	LHD (EIMCO)
Kipp	Longwall Test Mine	Walk	HD (shuttle car)
#9B	Room & Pillar	FSV (ELMAC) Manriding Conveyor belt	FSV (ELMAC) LHD (EIMCO) HD (shuttle car) HD (scoop tram)
#9G	Developed	Walk	LHD (EIMCO) HD (shuttle car)

TABLE 3.5

BRITISH COLUMBIA UNDERGROUND COAL MINES
PERSONNEL AND MATERIALS TRANSPORTATION

Name of Mine	Mining Method	Personnel Transport	Material Transport
Balmer North	Room & pillar	HD (scoop tram module)	HD (scoop tram) HD (shuttle car)
Balmer South	Hydraulic	FSV (EIMCO) FSV (ELMAC)	FSV (EIMCO) FSV (ELMAC) FSV (Hunslet)

TABLE 3.6

NOVA SCOTIA UNDERGROUND COAL MINES PERSONNEL AND MATERIALS TRANSPORTATION

Name of Mine	Mining Method	Personnel Transport	Material Transport
Lingan	Longwall advance Room & pillar	RVXP (inclined rope haulage using man cars) RVIP (diesel locomotive and man cars)	RVXP (inclined rope haulage using man cars) RVIP (diesel locomotive and man cars) HD (shuttle cars)
Prince	Longwall retreat	RVXP (inclined rope haulage using man cars) RVXP (inclined endless rope haulage using man cars)	RVXP (inclined rope haulage using man cars) RVXP (inclined endless rope haulage using man cars) HD (scoop tram) Air tugger
Donkin-Morien	Longwall retreat (planned)	Planning	Planning
Lingan-Phalen	Longwall retreat (planned)	Planning	Planning
#1B	Longwall retreat (planned)	Planning	Planning
Saint Rose	Room & pillar	RVXP (inclined rope haulage using coal cars)	RVXP (inclined rope haulage using coal cars)

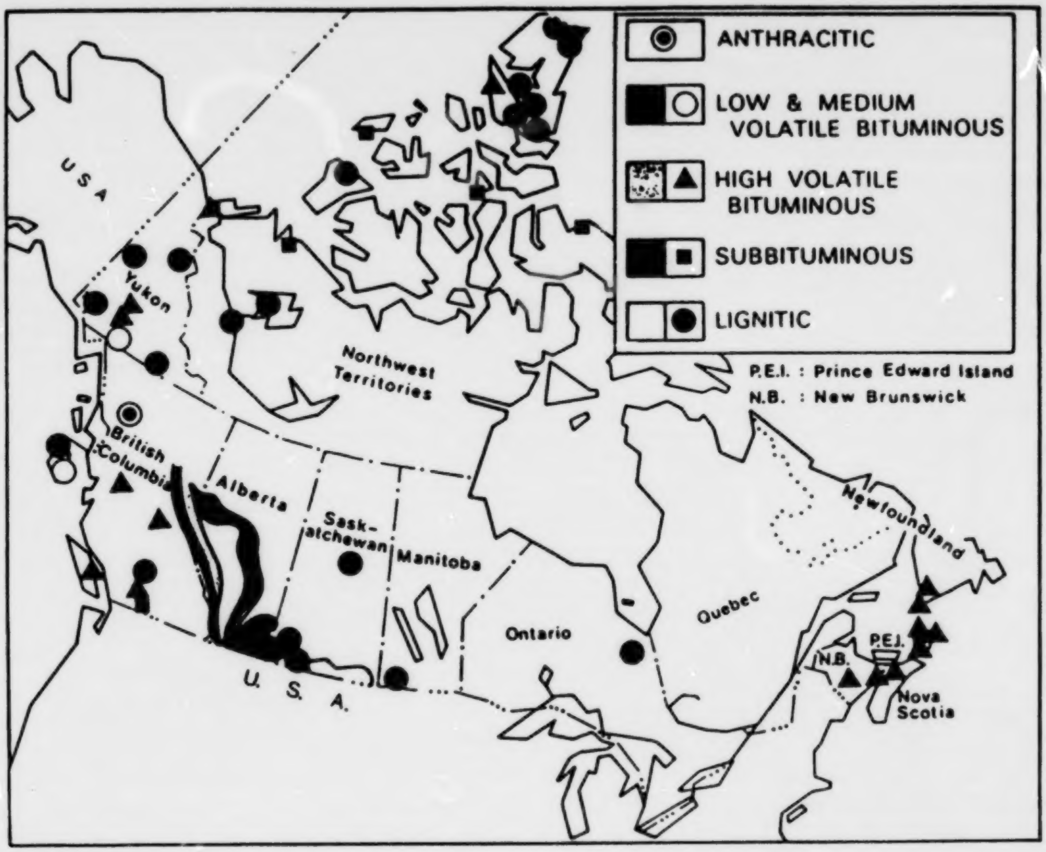

ANTHRACITIC
LOW & MEDIUM VOLATILE BITUMINOUS
HIGH VOLATILE BITUMINOUS
SUBBITUMINOUS
LIGNITIC
P.E.I. : Prince Edward Island
N.B. : New Brunswick
USA
Yukon
Northwest Territories
British Columbia
Alberta
Sask-atchewan
Manitoba
Ontario
Quebec
Newfoundland
N.B.
P.E.I.
Nova Scotia
U. S. A.

FIGURE 3-1
OCCURRENCES OF COAL IN CANADA

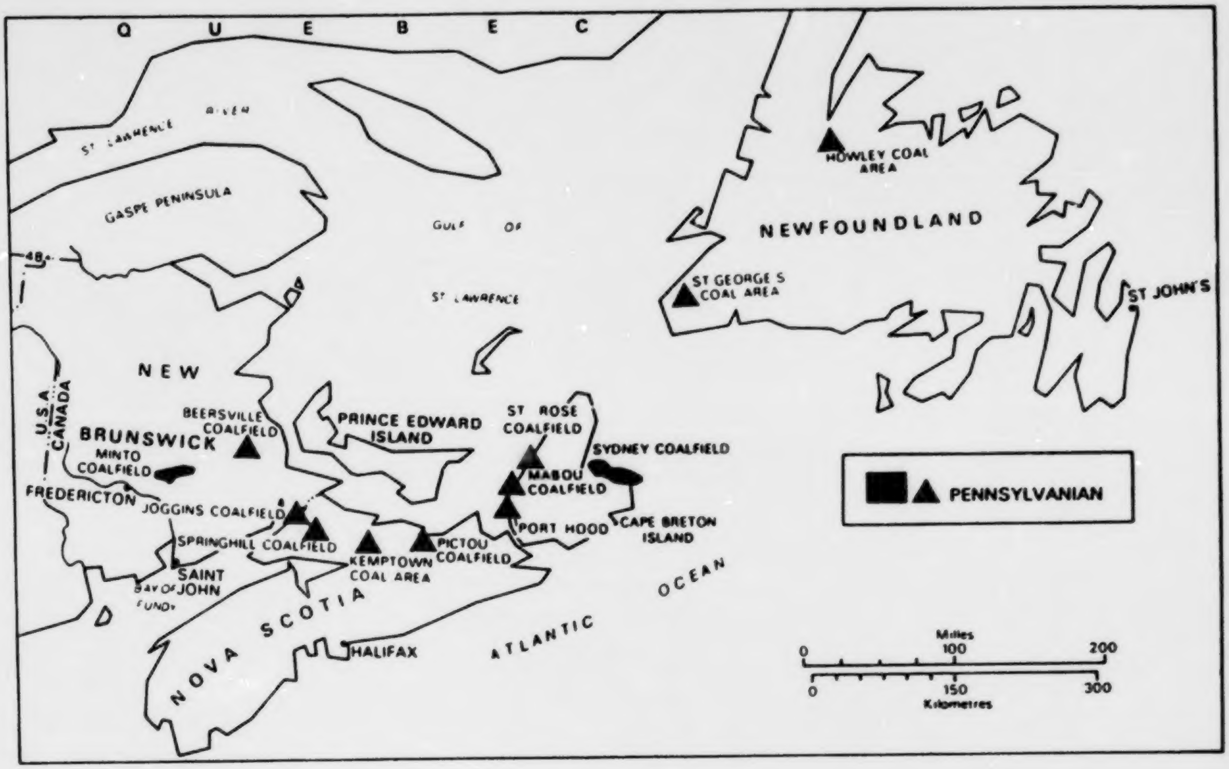

Q U E B E C
ST LAWRENCE RIVER
GASPE PENINSULA
GULF OF ST LAWRENCE
48
NEW BRUNSWICK
U.S.A. CANADA
BEERSVILLE COALFIELD
MINTO COALFIELD
FREDERICTON
JOGGINS COALFIELD
SPRINGHILL COALFIELD
SAINT JOHN
BAY OF FUNDY
PRINCE EDWARD ISLAND
ST ROSE COALFIELD
SYDNEY COALFIELD
MABOU COALFIELD
PORT HOOD
CAPE BRETON ISLAND
KEMPTOWN COAL AREA
PICTOU COALFIELD
NOVA SCOTIA
HALIFAX
ATLANTIC OCEAN
HOWLEY COAL AREA
NEWFOUNDLAND
ST GEORGE'S COAL AREA
ST JOHN'S
PENNSYLVANIAN
Miles
0
100
200
0
150
300
Kilometres

FIGURE 3-2
COAL DEPOSITS OF NEWFOUNDLAND, NOVA SCOTIA, NEW BRUNSWICK AND QUEBEC

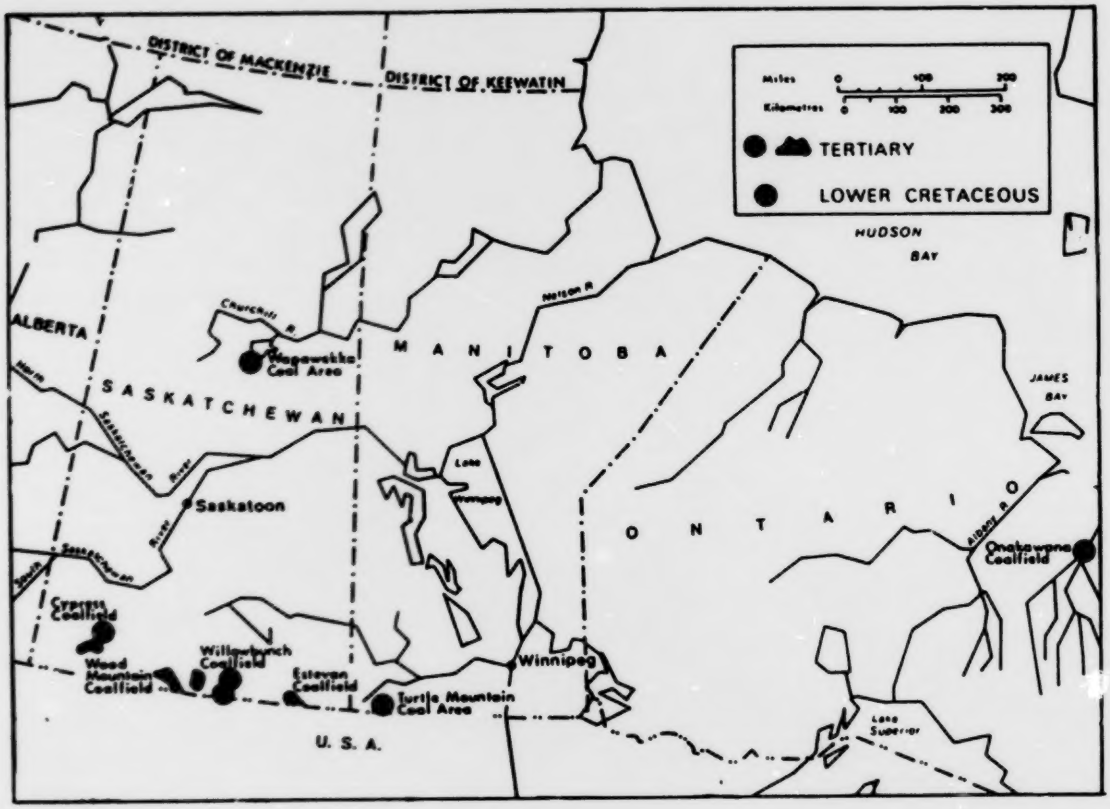

DISTRICT OF MACKENZIE
DISTRICT OF KEEWATIN
Miles 0 100 200
Kilometres 0 100 200 300
TERTIARY
LOWER CRETACEOUS
HUDSON BAY
JAMES BAY
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
Churchill R.
Nelson R.
North Saskatchewan River
South Saskatchewan River
Albany R.
Lake Winnipeg
Lake Superior
Wapawekka Coal Area
Saskatoon
Winnipeg
Cypress Coalfield
Wood Mountain Coalfield
Willowbunch Coalfield
Estevan Coalfield
Turtle Mountain Coal Area
Onakawana Coalfield
U. S. A.

FIGURE 3-3
COAL DEPOSITS OF ONTARIO, MANITOBA AND SASKATCHEWAN

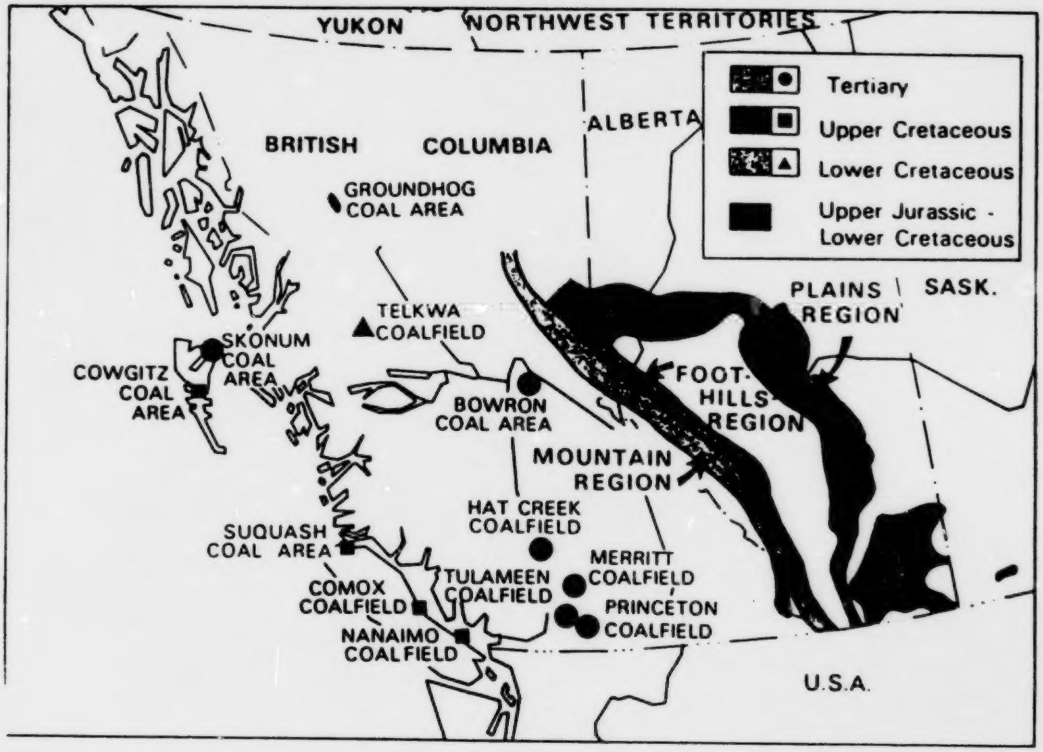

YUKON
NORTHWEST TERRITORIES
ALBERTA
BRITISH COLUMBIA
Tertiary
Upper Cretaceous
Lower Cretaceous
Upper Jurassic - Lower Cretaceous
GROUNDHOG COAL AREA
TELKWA COALFIELD
SKONUM COAL AREA
COWGITZ COAL AREA
BOWRON COAL AREA
PLAINS REGION
SASK.
FOOT-HILLS REGION
MOUNTAIN REGION
HAT CREEK COALFIELD
SUQUASH COAL AREA
MERRITT COALFIELD
TULAMEEN COALFIELD
COMOX COALFIELD
PRINCETON COALFIELD
NANAIMO COALFIELD
U.S.A.

FIGURE 3-4

COAL DEPOSITS OF ALBERTA AND BRITISH COLUMBIA

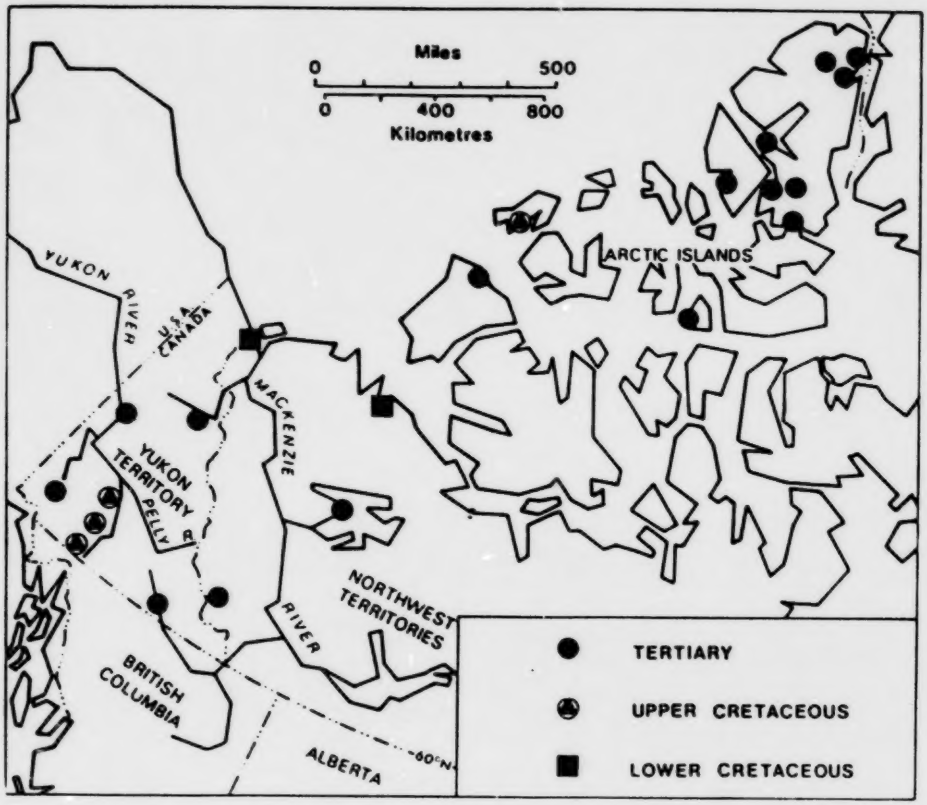

Miles
0
500
0
400
800
Kilometres
ARCTIC ISLANDS
YUKON RIVER
U.S.A.
CANADA
MACKENZIE RIVER
YUKON TERRITORY
PELLY R
NORTHWEST TERRITORIES
BRITISH COLUMBIA
ALBERTA
60°N
● TERTIARY
UPPER CRETACEOUS
■ LOWER CRETACEOUS

FIGURE 3-5
COAL DEPOSITS OF YUKON AND NORTHWEST TERRITORIES

SECTION 4

TECHNIQUES

4.1 INTRODUCTION

In this study, the equipment presently available for use in the transportation of personnel and materials in underground coal mines is classified in the following categories:

- Rail vehicles internal powered (RVIP)
- Rail vehicles external powered (RVXP)
- Free steered vehicles (FSV)
- Conveyors
- Miscellaneous transportation systems
- Ancilliary transportation systems
- Monitoring and control

Each of the first three principal categories is subdivided as to use, capacity and power. In the case of Rail Vehicles there is a further subdivision as to floor or roof mounting and non-trapped or trapped rail. For example an FMC utility car is classified as a Rail Vehicle Internal Powered, non-trapped floor mounted, medium, trolley personnel/materials.

In the case of Free Steered Vehicles there are further subdivisions as to generic name, power source and type of steering. Thus, a Memco A200 diesel material truck is described as a FSV, medium, truck, diesel, articulated.

As conveyors are all site specific they have not been identified by system, but information on components has been included.

For each of the subdivisons of the first three categories above, a typical piece of equipment was identified and a specification sheet was prepared summarizing the principal specifications of the unit in addition to general acceptability, costs, and an example of use. While every effort was made to ensure that these are error free, the manufacturer should be contacted for exact quotations and specifications.

A large number of manufacturers of transportation and related equipment provided data for the study. A partial list of manufacturers and their products is included in Appendix B-1, while addresses of manufacturers appears in B-2.

Equipment presently used in underground non-coal mines is included as well as selected equipment utilized in industry for surface transport of personnel and materials.

Shaft hoisting equipment and systems are excluded from this study. Also excluded are systems and equipment intended exclusively for the transport of coal, mineral or rock.

This section of the report addresses the categories:

- Rail Vehicles Internal Powered (RVIP)
- Rail Vehicles External Powered (RVXP)
- Free Steered Vehicles (FSV)
- Conveyors
- Miscellaneous Transportation Systems
- Ancilliary Transportation Systems
- Monitoring and Control

Each category is introduced by a general description of the equipment characteristics. For the first three categories a series of data sheets are provided (printed on colored paper) giving profiles of typical examples.

The information assembled in this section of the report provides a comprehensive data base for the transportation system designer. The classification developed enables appropriate sub-systems to be identified for inclusion in networks designed according to the site specific conditions at an individual mine. The classification emphasizes the two principal considerations of capacity and gradeability.

There is an extensive body of technical literature addressing personnel and materials transportation. A selected bibliography is provided in Appendix C.

4.2 RAIL VEHICLES INTERNAL POWERED (RVIP)

Definition

This group of rail vehicles includes all locomotive and train installations where the tractive effort is applied by the locomotive through a drawbar. Several different rail configurations can be used including trapped and non-trapped rails. Also included are self powered rail vehicles where each conveyance has an internal power source. The classification is illustrated in Figure 4-1.

Historical Development

The use of electric locomotives with trolley power supply in underground mining is as old as the electric drive itself. Trolley locomotives worked underground in Russia and U.S.A. before the turn of the century. Self propelled diesel and battery powered locomotives were introduced in the late 1930's. Their extra flexibility and absence of the hazardous trolley-wire made them very acceptable particularly in smaller mining operations. Beginning in the mid 1960's, the introduction of high speed belt conveyors and free steered vehicles brought about some decline in the use of locomotive transport. However, the rail vehicles are still a very important means of manriding and transport of materials.

Power Source

The power sources for RVIP's are trolley-electric, battery electric, diesel drive, trailing cable electric and a combination of power sources.

Trolley wire drive is widely accepted in the U.S.A. and European coal mines but not in the U.K. These systems require large cross-section roadways to accommodate the wires and pantograph assemblies safely. Trolley-electric rail vehicles have advantages in tractive effort, the ability to negotiate gradients and attain higher speeds.

Battery electric power is simple, reliable and battery powered locomotives have a moderate range of action. They are preferred for operation in trunk roadways where gradients are not steep. They are capable of moderate speeds and are extensively used in gassy mines.

Diesel engines are the least used power source in RVIP's. They introduce both heat and fumes to the mine environment and require more skilled maintenance.

Other non-conventional power sources such as compressed air, hydrogen engines, nitrogen, turbines and fly-wheel energy have been used. Compressed air locomotives were quite common in Canada until about 1955.

Excavation Requirements

Rail vehicles are used in roadways with widely varying dimensions. The vehicles do not require large clearances, however, in the interests of safety it is usual to provide refuge stations at regular intervals for personnel walking. Straight or nearly-straight excavations provide the ideal working environment of locomotive haulage although smaller units can negotiate very tight bends with some loss in speed.

Gradeability and Speed

The speed of RVIP's is primarily limited by the gradient on which they work. Conventional RVIP systems are never used in roadways with an inclination angle exceeding 2^{o}. In the U.S.A. the recommended gradient for high speed haulage is less than 1^{o}. For use on steeper gradients a widely accepted system for the transport of men and materials is trapped rail haulage. Locomotives using this system with recently developed polyurethane tires can negotiate gradients up to 7° providing the length of steep section is limited. Rack rail locomotives are also in use to negotiate gradients up to 18°.

Safety

Underground RVIP transport is one of the major sources of accidents in mining. Important elements in the safe operation of RVIP are efficient braking systems, proper design of roadways and intersections, signalling systems, design of manriding cars and proper maintenance.

Common causes of accidents related to RVIP are collisions with other transportation units, electric shocks from the trolley wire, improper positioning and fastening of carried materials and men not properly seated during travel.

Specially designed spring-applied, self adjusting integrated brake units have been developed for manriding cars. Other systems with fail safe devices that activate the brakes in the event of uncoupling or runaway accidents are in general use, as are friction arrestors to stop runaways and to halt overspeeding trains.

Other safety devices being used on RVIP are:

- special-design driver's cab with an adjustable seat, two position sliding doors and conveniently arranged controls
- signalling and shut-off devices for the control of manriding car doors

Automation of RVIP Transport Systems

One of the greatest advantages of RVIP transport is the possibility of automating the whole transport system. Automation of RVIP transport can contribute to in the safe operation of this kind of haulage. Automatic operation is widespread in mineral handling systems, but not in manriding where regulations frequently still require a human operator. Automation of RVIP systems has been successfully applied in the U.S.A. and other countries particularly in metal mines.

At the General Blumenthal coal mine, FRG, a completely automatic locomotive system, without drivers has been in operation since 1967. This installation, which is for coal haulage, has advantages in cost, efficiency and safety over manual locomotive and conveyor systems. In the U.S.A. a detailed investigation has been made into the design of a totally automated rail haulage system, using 50 tonne pantograph electric locomotives. Each locomotive has an on-board computer. As an example of the sophistication of the system the computer detects wheel slip and automatically initiates sanding whilst reducing power to the wheels. An infrared train presence detector is recommended for critical areas such as track intersections and also an automatic derailment detector which switches on the emergency brakes. One of the largest and most advanced underground automatic train transport systems is at Henderson Mine in the U.S.A. which incorporates twenty four 50 tonne D.C. electric locomotives in six trains made up of four locomotives and thirty mine cars each.

Further Development

There is a steady demand for RVIP developments particuarly in the area of speed increase, safety improvement, increase of durability, and cost reduction of the rolling stock and the rails.

At Mount Isa Mine, Australia, developments in the design of wheel tire profiles have extended tire life by 5% and the rail wear by 7%. An ultrasonic flaw detector is used to check rails for damage.

Mechanized track assembling and maintenance equipment is becoming more common but its applications underground are limited to large systems.

Developments in brake systems have an impact on speed increase and safety improvement.

A real advance in mining exploitation of RVIP may be through introduction of the Maglev railway system, employing the magnetic levitation effect of electro-magnetic fields. This system has no rotating parts and consequently very low running friction, and using the magnetic field for powerful braking promises a safer and cheaper alternative to conventional RVIP transportation.

Costs

Any RVIP transport system has the disadvantage of high initial capital cost. This may be offset by low maintenance and operating costs and high output.

Supplies

A partial list of manufacturers of RVIP equipment is provided in Table 4.1. Their addresses appear in Appendix B-2.

PVIP - Non-Trapped Floor Mounted - Small - Battery

Principal service		Personnel
Seating capacity		1-4
Driver position		Either end
Track Gauge (cm)		To customers requirements
Total Power (kw)		250
Engine Type		DC motor
Number		1
Voltage (V)		24
Rating (Ah)		60
Power Transmission		2 speed gearbox
Controller		Electronic
Brakes Service		Foot pedal
Parking		Yes
Rated Tractive Effort		Not rated
Speed at Rated Tractive Effort (km/h)		7
Gradeability:		Practical limit 5°
Dimensions (cm)	length	200
	width	84
	height	86
	wheel base	Not specified
Minimum Curve Radius (cm)		Not specified
Weight (kg)		280
Costs	Initial	$13,000
	Maintenance	Low
Safety		Good
Stability		Good
Ventilation Requirements		No special requirements except for battery charging.
Certification		Permissible (certifiable in Canadian coal mines).
Statutory Requirements		Special limitations
Case history		Widely used in Republic of West Germany
Typical Manufacturer		Scharf Battery Buggy

RVIP - Non-Trapped Floor Mounted - Small - Battery Locomotive

Principal service		Production
Seating capacity		1
Driver position		Front, side facing
Track Gauge (cm)		45 to 61
Total Power (kw)		4.5
Engine Type		DC traction motor
Number		1
Voltage (V)		48
Rating (Ah)		252
Power Transmission		Worm reduction
Controller		3-speed drum type
Brakes Service		Mechanical drum brake
Parking		Yes
Rated Tractive Effort		193 kg at 1 hr rate
Speed at Rated Tractive Effort (km/h)		7.2
Gradeability:		Practical limit 3°
Dimensions (cm)	length	176
	width	93
	height	115
	wheel base	65
	wheel dia.	40
Minimum Curve Radius (cm)		Not specified
Weight (kg)		1500
Costs	Initial	$39,500
	Maintenance	Low
Safety		Good
Stability		Good
Ventilation Requirements		No special requirements except for battery charging.
Certification		Permissible vehicles available (certifiable in Canadian coal mines).
Statutory Requirements		Specific limitations.
Case history		C.S.R. Paringa, Kalgoorlie, West Australia
Typical Manufacturer		Gemco (1.5 tonnes)

RVIP - Non-Trapped Floor Mounted - Small - Bicycle

Principal service		Personnel
Seating capacity		2
Driver position		Front
Track Gauge (cm)		107-122
Total Power (kw)		2 man pedals
Engine Type		No engine
Power Transmission		Chain drive
Controller		-
Brakes Service		Wheel
Parking		Yes
Rated Tractive Effort		-
Speed at Rated Tractive Effort (km/h)		-
Gradeability:		-
Dimensions (cm)	length	190
	width	Dependent on track gauge
	height	90
	wheel base	+60
Minimum Curve Radius (cm)		Not specified
Weight (kg)		-
Costs	Initial	Not given
	Maintenance	Low
Safety		Good
Stability		Good
Ventilation Requirements		No specific requirements
Certification		Permissible
Statutory Requirements		None
Case history		Zolder Mine, Belgium
Typical Manufacturer		Scharf Scooter

RVIP - Non-Trapped Floor Mounted - Medium - Battery Locomotive

Principal service		Production
Seating capacity		1
Driver position		Front, side facing
Track Gauge (cm)		61-91
Total Power (kw)		62
Engine Type		Series wound traction motors
Number		2
Voltage (V)		140
Rating (Ah)		1
Power Transmission		Traction type
Controller		Variable speed controller
Brakes Service		Lever brake
Parking		Screw operated
Rated Tractive Effort		1700 kg
Speed at Rated Tractive Effort (km/h)		7.2
Gradeability:		2°
Max. Speed (km/h)		20
Dimensions (cm)	length	375
	width	Dependent on track guard
	height	200
	wheel base	120
	wheel dia.	Not specified
Minimum Curve Radius (cm)		Not specified
Weight (kg)		8170
Costs	Initial	$140,000
	Maintenance	Low
Safety		Good
Stability		Good
Ventilation Requirements		No specific requirements except for battery charging.
Certification		Permissible
Statutory Requirements		Specific limitations.
Case history		Falconridge, Ontario
Typical Manufacturer		Clayton 50 hp/9t

RVIP - Non-Trapped Floor Mounted - Medium - Battery/Trolley Locomotive

Principal service		Production
Seating capacity		1-2
Driver position		Front, side facing
Track Gauge (cm)		91-122
Total Power (kw)		14
Engine Type		DC
Number		1
Voltage (V)		96
Rating (Ah)		1
Power Transmission		Worm transmission
Controller		Single end conactor type
Brakes Service		Hand operated
Parking		Screw type
Rated Tractive Effort		See performance curve
Speed at Rated Tractive Effort (km/h)		13
Gradeability:		Practical limit 5°
Dimensions (cm)	length	550
	width	Dependent on track gauge
	height	80
	wheel base	200
	wheel dia.	66
Minimum Curve Radius (cm)		Not specified
Weight (kg)		9080
Costs	Initial	$115,000
	Maintenance	Low
Safety		Good
Stability		Good
Ventilation Requirements		No special requirements.
Certification		Permissible.
Statutory Requirements		Special limitations.
Case history		North River Energy, North Port, Alabama
Typical Manufacturer		Goodman 10T

RVIP - Non-Trapped Floor Mounted - Medium - Diesel Locomotive

Principal service		Production
Seating capacity		1
Driver position		Front, side facing
Track Gauge (cm)		60-91
Total Power (kw)		112
Engine Type		Diesel (Cat Deuta)
Number		-
Voltage (V)		-
Rating (Ah)		-
Power Transmission		Hydrostatic
Controller		-
Brakes Service		Hydrostatic dynamic
Parking		Air brakes on all four wheels
Rated Tractive Effort		2270 kg
Speed at Rated Tractive Effort (km/h)		Not rated
Gradeability:		Practical limited 5^o
Dimensions (cm)	length	Dependent on engine selection
	width	Dependent on wheel gauge
	height	180
	wheel base	200
	wheel dia.	61
Minimum Curve Radius (cm)		580 - 850
Weight (kg)		7,250 - 14,500
Costs	Initial	$95,000
	Maintenance	High
Safety		Good
Stability		Good
Ventilation Requirements		Specific requirements dependent on engine HP and exhaust emissions.
Certification		Permissible.
Statutory Requirements		Specific limitations.
Case history		Federal Mining, Elkhorn City, Kentucky
Typical Manufacturer		Brookville 10T

RVIP - Non-Trapped Floor Mounted - Medium - Trolley Locomotive

Principal service		Production
Seating capacity		1
Driver position		Front, side facing
Track Gauge (cm)		110-120
Total Power (kw)		45
Engine Type		DC traction motors
Number		2
Voltage (V)		250
Rating (Ah)		Not rated
Power Transmission		Gear
Controller		Single end manual
Brakes Service		Dynamic braking
Parking		Air
Rated Tractive Effort		1600 kg
Speed at Rated Tractive Effort (km/h)		10
Gradeability:		Practical limit 5°
Dimensions (cm)	length	440
	width	167
	height	74
	wheel base	173
	wheel dia.	50
Minimum Curve Radius (cm)		760
Weight (kg)		5450
Costs	Initial	$155,000
	Maintenance	Low
Safety		Good
Stability		Excellent
Ventilation Requirements		No specific requirements.
Certification		Permissible
Statutory Requirements		Specific limitations.
Case history		Donaldson Mining, Charleston, West Virginia
Typical Manufacturer		Jeffrey 6007

RVIP - Non-Trapped Floor Mounted - Medium - Trolley (Personnel/Material Cars)

Principal service		Personnel/material
Seating capacity		1-14
Driver position		Either end, forward facing
Track Gauge (cm)		106-110
Total Power (kw)		6
Engine Type		250 or 500 DC trolley
Number		2
Voltage (V)		250
Rating (Ah)		Not rated
Power Transmission		Gear
Controller		Step controller
Brakes Service		Hydraulic disc
Parking		Air
Rated Tractive Effort		Not specified
Speed at Rated Tractive Effort (km/h)		Not specified
Gradeability:		Practical limit 5°
Dimensions (cm)	length	530
	width	205
	height	110
	wheel base	170
	wheel dia.	40
Minimum Curve Radius (cm)		Not specified
Weight (kg)		Not specified
Costs	Initial	$60,000
	Maintenance	Low
Safety		Good
Stability		Excellent
Ventilation Requirements		No specific requirements.
Certification		Permissible.
Statutory Requirements		Specific limitations.
Case history		Consolidated Coal, Moundsville, West Virginia
Typical Manufacturer		FMC 2220

RVIP - Non-Trapped Floor Mounted - Large - Battery Locomotive

Principal service		Material
Seating capacity		1
Driver position		End, side facing
Track Gauge (cm)		107-120
Total Power (kw)		142
Engine Type		MH 2409 DC
Number		2
Voltage (V)		250
Rating (Ah)		1
Power Transmission		Gear
Controller		Solid state
Brakes Service		Dynamic
Parking		Screw operated
Rated Tractive Effort (kg)		3900
Speed at Rated Tractive Effort (km/h)		9.8
Gradeability:		Practical limit 3°
Dimensions (cm)	length	760
	width	245
	height	100
	wheel base	265
	wheel dia.	68
Minimum Curve Radius (cm)		131
Weight (kg)		9490
Costs	Initial	$320,000
	Maintenance	Medium
Safety		Good
Stability		Good
Ventilation Requirements		No specific requirements
Certification		Permissible
Statutory Requirements		Specific limitations
Case history		McClure Mine, Clinchfield, Ohio
Typical Manufacturer		Jeffrey 6225

RVIP - Non-Trapped Floor Mounted - Large - Battery Unit Train

Principal service		Personnel/material
Seating capacity		24-40
Driver position		Both ends
Track Gauge (cm)		70-92
Total Power (kw)		48
Engine Type		DC
Number		8
Voltage (V)		57
Rating (Ah)		1
Power Transmission		-
Controller		Thyristor
Brakes Service		Electric
Emergency		Spring applied fail safe
Parking		On six axles
Rated Tractive Effort (kg)		1500
Speed at Rated Tractive Effort (km/h)		15
Gradeability:		Practical limit 6°
Dimensions (cm)	length	2850
	width	120
	height	140
	wheel base	520-610
	wheel dia.	46
Minimum Curve Radius (cm)		500
Weight (kg)		-
Costs	Initial	$245,000
	Maintenance	High
Safety		Excellent
Stability		Excellent
Ventilation Requirements		No special requirements.
Certification		Permissible design.
Statutory Requirements		Specific limitations.
Case history		Gedling Colliery, U.K.
Typical Manufacturer		Clayton Unit Train

RVIP - Non-Trapped Floor Mounted - Large - Diesel Locomotive

Principal service		Production, personnel/material
Seating capacity		1
Driver position		Both ends, front facing
Track Gauge (cm)		60-168
Total Power (kw)		105
Engine Type		6 cy diesel injection
Number		1
Voltage (V)		-
Rating (Ah)		-
Power Transmission		3 speed
Controller		-
Brakes Service		Air
Emergency		Air
Parking		Spring applied
Rated Tractive Effort (kg)		4500
Speed at Rated Tractive Effort (km/h)		18
Gradeability:		Practical limit 5°
Max. Speed (km/h)		40
Dimensions (cm)	length	580
	width	Dependent on gauge
	height	170
	wheel base	210
	wheel dia.	-
Minimum Curve Radius (cm)		Not specified
Weight (kg)		13,620
Costs	Initial	$330,000
	Maintenance	High
Safety		Good
Stability		Good
Ventilation Requirements		Specific requirements dependent on HP and exhaust emissions.
Certification		Permissible.
Statutory Requirements		Special limitations.
Case history		Etibank, Anrara, Turkey
Typical Manufacturer		Clayton 140 HP/15 T

RVIP - Non-Trapped Floor Mounted - Large - Trolley Locomotive

Principal service		Production/Material/ Personnel
Seating capacity		1
Driver position		Forward front facing
Track Gauge (cm)		91
Total Power (kw)		450
Engine Type		DC
	Number	4
	Voltage (V)	250
	Rating (Ah)	1
Power Transmission		Gear
Controller		Electropneumatic
Brakes Service		Air
	Parking	Screw type
Rated Tractive Effort (kg)		8400
Speed at Rated Tractive Effort (km/h)		17
Gradeability:		Limited to approximately 5%
Dimensions (cm)	length	1060
	width	188
	height	115-130
	wheel base	Not specified
	wheel dia.	80-84
Minimum Curve Radius (cm)		Not specified
Weight (kg)		31,000
Costs	Initial	$485,000
	Maintenance	Low
Safety		Good
Stability		Excellent
Ventilation Requirements		No specific requirement.
Certification		Permissible.
Statutory Requirements		Specific limitations.
Case history		Bethlehem Mines Corporation, Eighty-four, Pennsylvania
Typical Manufacturer		Jeffrey 6044

RVIP - Trapped Floor Mounted - Small - Battery Locomotive

Principal service		Production/Material
Seating capacity		1
Driver position		Front, side facing
Track Gauge (cm)		-
Total Power (kw)		2.5
Engine Type		DC
	Number	2
	Voltage (V)	24
	Rating (Ah)	420
Power Transmission		Gear
Controller		Step
Brakes Service		-
	Parking	-
Rated Tractive Effort		Not specified
Speed at Rated Tractive Effort (km/h)		Not specified
Gradeability:		Practical limit 3°
Max. Spped (km/h)		11
Dimensions (cm)	length	458
	width	Dependent on track guage
	height	-
	wheel base	-
	wheel dia.	-
Minimum Curve Radius (cm)		Not specified
Weight (kg)		1750
Costs	Initial	$43,500
	Maintenance	Medium
Safety		Good
Stability		Excellent
Ventilation Requirements		No specific requirements.
Certification		Permissible
Statutory Requirements		Specific requirements
Case history		Mostly used in sewer tunnelling.
Typical Manufacturer		Scharf Stollenkuli 78

RVIP - Trapped Floor Mounted - Medium - Battery Locomotive

Principal service		Production/Personnel/ Material
Seating capacity		1-40+
Driver position		Both ends
Track Gauge (cm)		Not applicable
Total Power (kw)		10.5
Engine Type		DC motors
Number		2
Voltage (V)		108
Rating (Ah)		400
Power Transmission		Gear
Controller		Electronic
Brakes Service		-
Parking		-
Rated Tractive Effort (kw)		30
Speed at Rated Tractive Effort (km/h)		7.2
Gradeability:		Practical limit 3°
Dimensions (cm)	length	1100
	width	95
	height	110
	wheel base	Not applicable
	wheel dia.	-
Minimum Curve Radius (cm)		110 vertical 40 horizontal
Weight (kg)		-
Costs	Initial	Under development
	Maintenance	High
Safety		Good
Stability		Excellent
Ventilation Requirements		No specific requirements.
Certification		Permissible
Statutory Requirements		Specific limitations.
Case history		Under development
Typical Manufacturer		Scharf Streckenkuli 500

RVIP - Trapped Floor Mounted - Medium - Diesel Locomotive

Principal service		Personnel/Material
Seating capacity		20+
Driver position		Both ends, forward facing
Track Gauge (cm)		-
Total Power (kw)		336
Engine Type		Diesel
Number		-
Voltage (V)		-
Rating (Ah)		-
Power Transmission		Hydrostatic
Controller		Throttle
Brakes Service		-
Parking		-
Rated Tractive Effort		See performance chart
Speed at Rated Tractive Effort (km/h)		See performance chart
Gradeability:		Max. 12°
Dimensions (cm)	length	780
	width	107
	height	135
	wheel base	-
	wheel dia.	-
Minimum Curve Radius (cm)		400
Weight (kg)		5950
Costs	Initial	Dependent on design.
	Maintenance	High
Safety		Good
Stability		Excellent
Ventilation Requirements		Specific requirements dependent upon engine HP and exhaust emissions.
Certification		Permissible
Statutory Requirements		Specific requirements
Case history		Used in U.K. & Republic of West Germany
Typical Manufacturer		Becorit RL50/400 Railroader Locomotive

RVIP - Trapped Floor Mounted - Medium - Rack and Pinion/ATC Rail/Electric

Principal service		
Seating capacity		1 - 60 men in 6 cars or 1 - 10 men in car + 3 material cars of 5 tons payload each
Driver position		Front, forward facing
Track Gauge (cm)		107
Total Power (kw)		300
Engine Type		Permanent magnet electric
Number		1
Voltage (V)		DC, 500 v
Rating (Ah)		
Power Transmission		
Controller		Electronic
Brakes Service		4 brake cars
Parking		Emergency & parking
Rated Tractive Effort		
Speed at Rated Tractive Effort (km/h)		7.2
Gradeability:		Max. 45°
Max. Speed (m/s)		5
Dimensions (cm)	length	Dependent on number of cars
	width	110
	height	100
	wheel base	N.A.
	wheel dia.	54
Minimum Curve Radius (cm)		130
Weight (kg)		29,964
Costs	Initial	$600,000+rail+trolley
	Maintenance	High
Safety		Excellent
Stability		Excellent
Ventilation Requirements		No specific requirements.
Certification		Permissible
Statutory Requirements		Specific limitations.
Case history		Sakog, Austria
Typical Manufacturer		Scharf Rack Train 140/600

RVIP - Trapped Roof Mounted - Medium - Battery Locomotive

Principal service		Production/Material/ Personnel
Seating capacity		1+ (30 persons in three cabins or 60 persons on three benches)
Driver position		Front facing, either end
Track Gauge (cm)		Monorail
Total Power (kw)		43
Engine Type		Battery
Number		2
Voltage (V)		108
Rating (Ah)		400
Power Transmission		Gearbox
Controller		Electronic
Brakes Service		-
Parking		-
Rated Tractive Effort (kw)		42
Speed at Rated Tractive Effort (km/h)		7.2
Gradeability:		Max. 27°
Dimensions (cm)	length	2620
	width	110
	height	170
	wheel base	410-500
	wheel dia.	45
Minimum Curve Radius (cm)		-
Weight (kg)		7,100-15,000
Costs	Initial	$186,000
	Maintenance	High
Safety		Excellent
Stability		Excellent
Ventilation Requirements		No specific requirements
Certification		Permissible
Statutory Requirements		Specific limitations
Case history		Heinrich Robert Colliery, Republic of West Germany
Typical Manfacturer		Scharf Monorail Battery Locomotive Type BC43-2-28

RVIP - Trapped Roof Mounted - Medium - Diesel Locomotive

Principal service		Material/Personnel/ Production
Seating capacity		1-63
Driver position		Both ends, front facing
Track Gauge (cm)		Monorail
Total Power (kw)		66
Engine Type		6 cy diesel MWM
Number		Canadian approved
Voltage (V)		-
Rating (Ah)		-
Power Transmission		Hydraulic
Controller		Throttle
Brakes Service		-
Parking		-
Rated Tractive Effort (km)		63
Speed at Rated Tractive Effort (km/h)		7.2
Gradeability:		Max. 27°
Dimensions (cm)	length	600
	width	90
	height	105
	wheel base	Not applicable
	wheel dia.	45
Minimum Curve Radius (cm)		Horizontal 40, vertical 100
Weight (kg)		5353
Costs	Initial	$162,000
	Maintenance	High
Safety		Excellent
Stability		Excellent
Ventilation Requirements		Specific requirements depending on engine HP and exhaust emissions.
Certification		Permissible. (Is permissible for use in Canadian coal mines).
Statutory Requirements		Specific limitations
Case history		Nordrhein-Westfalen Republic of West Germany
Typical Manufacturer		Scharf Monorail Diesel Locomotive 90 HP.

4.3 RAIL VEHICLES EXTERNAL POWERED (RVXP)

Definition

This group of rail vehicles consists of those which are rope hauled (Figure 4-2). Both trapped and non-trapped rail may be used.

The main types of rope haulage systems are:

- Single drum
- Double drum
- Endless rope
- Main and tail rope

Features of RVXP Systems

Rope haulage is a relatively inexpensive, extensively used, easily maintained and reliable method of transporting men and materials.

The gradeability of rope haulage rail systems, and the ease with which they can be extended has encouraged their use over the last 100 years. Extendable rope haulages are often used in advancing gate roadways in coal mines where the gradient would prohibit the use of locomotives.

The successful operation of rope hauled, high speed personnel and materials transport installations requires the following:

- Use of articulated "gondola" type vehicles with sprung undercarriage.
- Good track, on line and grade.
- A clean dry roadway.
- Adequate support of the haulage rope by rollers.

- Rollers fitted with sealed-for-life, double row ball bearings which help to reduce the slip between rope and rollers during acceleration. This also reduces the formation of martensite in the wire of the rope.
- The use of large diameter surge wheels, deflection and return wheels to minimize bending stresses in the rope.
- A general high standard of installation and maintenance.
- Means of giving controlled acceleration and deceleration to the haulage engine.
- A rope that gives sufficient flexibility while having strands with wires of adequate diameter to allow for an acceptable wear life.
- The correct number of laps on the surge wheel to give adequate surging action across the wheel and thus minimize wear.
- Correct rope tensioning arrangements.
- Relatively straight roadways.

Power Source

The dominant power source of RVXP is the electric motor drive. Due to the stationary character of the drive of the rope haulage, the use of diesel and compressed air power is usually limited to installations which are temporary such as those employed during initial mine development or for auxiliary transport.

A major development in the RVXP power train system was implementation of a hauler with hydraulic transmission. Where controlled speeds along any portion of a roadway are desirable, and where severe gradients are encountered, hydraulic control has definite advantages. A smaller electric drive may be feasible when a hydraulic transmission is used in place of direct electric drive.

Safety and Control

Control of RVXP traffic and the safety of the operation are strongly interrelated. Factors considered important for efficient operation will also contribute significantly to reduction of the hazard potential.

Of particular importance are the reduction of the numbers of men involved in operating the system and mechanizing potentially hazardous transfers and trans-shipments.

The remote control of rope haulage has advantages in both manpower saving and improved safety. Materials handling systems, particularly in gate roadways, can be controlled from within the roadway rather than by transmitting signals to the haulage driver. This system is advantageous from a safety viewpoint but a pre-start alarm is essential. Typically, control stations would be at 50 m intervals along the roadway and would be accessed by a special key. An emergency stop pull wire should always be installed along the roadway. Broken strand detectors as well as rope overload, rope slip, rope overspeed, and fire detectors have also been fitted to remotely controlled rope haulage systems.

Protection against such risks as vehicle runaway following a broken rope is critical. Entry into haulage roadways by personnel not engaged in operations must be controlled and the development of automatic signalling systems which warn personnel of the proximity of rope haulage equipment or sound alarms on simple entry into the ropeway may be a useful safety development.

Costs

Initial capital cost, as well as operating and maintenance costs are relatively low for most RVXP systems. Implementation of remote control and automation have a significant impact on the overall operating costs.

Further Developments

The increasing number of long haul routes and the deepening of existing mines will require higher speed rope systems. Development is required in the areas of mechanized tracklaying, designs for specialized and modular carriages as well as in failure control, signalling and the application of trapped rails.

It is expected that some future development work will be concentrated on the power train to develop a continuously varying speed control to accommodate different loads and roadway configurations.

Supplies

A partial list of manufacturers of RVXP equipment is provided in Table 4.2. Their addresses appear in Appendix B-2.

RVXP - Non-Trapped Floor Mounted - Medium - Hoist Double Drum

Principal service		Personnel/Material
Seating capacity		120 men
Driver position		Hoist driver
Track Gauge (cm)		91
Total Power (kw)		410
Engine Type		Electric
Number		1
Voltage (V)		2200
Power Transmission		Geared
Controller		Overspeed and overwind control
Brakes Service		Caliper spring applied
Parking		Emergency control valve in leading & rear cars
Speed (km/h)		12.8
Gradeability:		Designed for 6°
Dimensions (cm)	length	3,200
	width	125
	height	125
	wheel base	30
	wheel dia.	40
Minimum Curve Radius (cm)		Not specified
Weight (kg)		Empty, loaded
Costs	Initial	Dependent on design capacity.
	Maintenance	Medium
Safety		Good
Stability		Good
Ventilation Requirements		No special requirements.
Certification		Certified for use in Canadian coal mines.
Statutory Requirements		Specific requirements.
Case history		Lingan Mine, New Waterford, Cape Breton Island
Typical Manufacturer		Cape Breton Development Corporation, (J.T. Hepburn Hoist, Lebus Grooving, Sheepbridge cars.)

RVXP - Trapped Floor Mounted - Large - Endless Rope

Principal service		Personnel/Materials
Seating capacity		120-240
Driver position		Front forward facing & hoist driver
Track Gauge (cm)		40
Total Power (kw)		110-370
Engine Type		Electric
Number		1
Voltage (V)		As required
Power Transmission		Hydraulic or speed reducer
Controller		Thryistor
Brakes Service		Hoist brakes. Automatic brake system on master. Towing vehicles
Parking		Manual operation
Speed (km/h)		2.7-6.7
Gradeability:		5°
Dimensions (cm)	length	3100-6100
	width	140
	height	190
	wheel base	N.A.
	wheel dia.	Not given
Minimum Curve Radius (cm)		1200
Weight (kg)	empty	9600-20,400
	loaded	19,300-36,700
Costs	Initial	Dependent on design.
	Maintenance	High
Safety		Excellent
Stability		Excellent
Ventilation Requirements		No special requirements
Certification		Certified for all NCB specifications.
Statutory Requirements		Specific requirements.
Case history		Widely used in U.K. & Republic of West Germany
Typical Manufacturer		Becorit 400 mm Roadrailer

RVXP - Trapped Roof Mounted - Large - Endless Rope

Principal service		Personnel/Materials
Seating capacity		Dependent on design, 8 passengers/bench
Driver position		Front, forward facing & hoist driver
Track Gauge (cm)		Single rail
Total Power (kw)		Up to 110
Engine Type		Air or electric
Voltage (V)		As required
Power Transmission		Hydraulic or speed reducer
Controller		-
Brakes Service		Overspeed governor
Parking		Emergency brake trolley
Speed at (km/h)		Up to 14.5
Gradeability:		Max. 45°
Dimensions (cm)	length	Dependent on design capacity
	width	75
	height	160
	wheel base	N.A.
	wheel dia.	Not given
Minimum Curve Radius (cm)		400 horizontal or vertical
Weight (kg)		Dependent upon design
Costs	Initial	Dependent on design
	Maintenance	High
Safety		Excellent
Stability		Excellent
Ventilation Requirements		-
Certification		Certified for all NCB specifications.
Statutory Requirements		Specific requirements.
Case history		Walsum Colliery, Republic of West Germany
Typical Manufacturer		Scharf Monorail System

4.4 FREE STEERED VEHICLES (FSV)

Definition

Free steered vehicles (FSV) describes a group of self propelled, rubber-tired, mobile machines which can be categorized as shown in Figure 4-3. FSV's include load-haul-dump (LHD) equipment, haul-dump (HD) equipment, as well as specialized equipment for drilling, bolting etc. A summary of FSV equipment by manufacturer is provided in Table 4.3. A list of addresses is provided in Appendix B-2.

Historical Development

One of the most revolutionary innovations in underground coal transport was the introduction of a battery powered, rubber-tired shuttle car. This was introduced into the United States by Joy Manufacturing during the Second World War.

The development of FSV's continued and other significant underground mining equipment designs were introduced. EIMCO introduced an air powered and a diesel powered overshot loader mounted on caterpillar type tracks. The Wagner Brothers developed a rubber-tired diesel powered Free Steered Load Haul Dump Vehicle for use underground. With the introduction of all wheel drive and articulated steering LHD's came into widespread use in the 1960's in underground hard rock mines. With the adaption of flame proof and explosion proof construction, FSV's were then introduced into underground coal mines.

The recognition of the role of FSV's for non-production use came in the early 1970's and this has led to the development of a range of vehicles suited to the transport of personnel and material. At present over 20 manufacturers in the western world offer a wide range of specialized FSV's for use in underground coal mines.

Power Source

The majority of FSV's are powered by diesel engines which provide long range and high power output. Others have electric motors powered by batteries or cable reel. Compressed air powered FSV's are also available but have limited use in underground mining.

Gradability and Speed

The main features of FSV's are their relatively high speeds, gradeability and manouverability.

The speed of FSV's in mining operations are limited by the following factors:

- excavation dimensions
- roadway gradient
- roadway conditions
- type of wheel drive
- tire condition
- equipment design
- regulatory limits

In practice, maximum gradients of mine roadways does not usually exceed 15°. For example, at Carmaux Combined Mine in France scoop trams operate satisfactorily on coal floors at gradients up to 14°. In certain circumstances FSV's can be used over short distances and at low speed on gradients considerably in excess of 15°.

Roadway Surfaces

Good roadway surfaces are the key to successful operation of trackless vehicles in underground coal mines. Rolling resistance will vary considerably from a hard smooth floor to a soft muddy rutted roadway. Generally trackless vehicles can be used on unsurfaced floors but uneven, soft and muddy floors present hazards, especially to high speed vehicles. Good drainage can considerably improve road surface conditions but if this is not effective some type of roadway surfacing must be used. In the U.S.A., "corduroy" and planking are used for surfacing in wet conditions. In the U.K. precast concrete slabs have been used. The French coal industry has developed a surface of gravel and ash bound together with a bituminous emulsion which can be laid on a roadway and compacted with a vibratory roller to give an even and solid surface in dry conditions. Where roadways have a short life a compacted water bound mixture of gravel and ash can be used to form a temporary surface. The National Coal Board is experimenting with roadway surfacing including the use of cement to stabilize existing floor material. Trials have been carried out with motor graders designed for underground use to level and compact natural floor material.

Steering

Manufacturers have tried numerous methods to improve the maneuverability of FSV's. Articulated steering is a common feature of FSV design and it is claimed that this improves both manoeuvrability and tracking. A Swedish firm has developed a rubber tired vehicle in which one lever controls the steering of all four wheels, which may be turned to enable the vehicle to travel diagonally. In the U.S.A. six wheel shuttle cars are used but these are less manoeuvrable than the conventional four wheeled vehicles. Power steering is now considered essential for larger FSV's.

Restricted driver's vision is a serious problem, particularly in low coal seams, and visual displays to aid manual steering are very desirable. A FSV equipped with a pulsed laser optical ranging system to provide guidance for an automatic steering system has been tested in producing coal mines in the U.S.A. The automatic steering keeps the car centered in a roadway and turns are made at intersections as signalled by the operator. For safety the steering can be manually overridden. The system is now undergoing further development.

Tires

The replacement of worn tires represents a considerable proportion of the running cost of FSV's. In mines tire wear typically represents 10% to 20% of the total operating cost.

The use of armoured chains has been found to reduce tire wear considerably in metalliferous mines and in some cases tire life has been extended ten fold. Concrete road surfaces have shown no signs of excessive wear when used by FSV's fitted with chains. To combat the problem of chains becoming elongated with internal wear of the links, self tensioning protection chains have been developed. This system also provides protection against chain overload, which may lead to failure, since jerky movements such as spinning of wheels are immediately compensated by the tensioning elements. However, chains can be used and indeed there are some advantages in using them on bald tires.

Water filling of tires has been successfully applied by a number of companies. This has the additional advantage of increasing tire life by reducing the leakage often associated with air filled tires. In the U.S.A. there is a trend towards the use of foam filled tires which provide pneumatic cushioning without the maintenance required by conventional tires.

Safety and Safety Devices

FSV's have no restraints on their movements and can only be used with safety in roadways with adequate clearances. When several trackless vehicles are used there must be either passing places in the roadways or an alternative return route.

Most accidents with FSV's involve the collision of vehicles with roadway supports. Numerous accidents have been recorded where a victim has been crushed between the vehicle and roof or rib. A few jack-knifing accidents have occurred in the U.S.A. with tractor-trailer type vehicles. Considerable emphasis is placed on training of drivers for FSV's to improve standards of safety.

The comfort and safety of the operator is one of the primary considerations in the design of FSV's. Research has been undertaken in the U.S.A., using a human engineering approach, to improve operator safety and visibility. Cabs are now common on FSV's to protect the operator against falls of rocks and collisions with obstructions in the roof of the roadway. At the Jenny coal mine in the U.S.A. all underground FSV's are fitted with cabs which can be raised or lowered approximately 0.5 m at the touch of a lever. The cabs can also rotate horizontally through 180 degrees, thus removing the necessity for dual controls for two directional operations. The advantages of these cabs are that the operator's eye level can be set for the maximum visibility commensurate with the height of the mine roof or roof support. Also, in the event of a roof fall the cab is lowered so that its roof is flush with the top of the vehicle thus distributing the load over the whole vehicle.

Diesel powered FSV's can operate in seams as low as 1 m but because diesel engines are tall and relatively bulky the operator has to sit at the side of the vehicle in thin seam operations. Consequently the operator is exposed to a very high noise level which in the U.S.A. is restricted by Federal regulations to eight hours at 90 dB (A). In a demonstration project the operators sound level for an underground diesel powered service vehicle was reduced from 101 dB(A) to 87 dB(A) by fitting a partial engine enclosure insulated with fibreglass and polyurethane foam. The enclosure was designed to allow easy access to the engine for maintenance. After a four month underground trial mine personnel were enthusiastic about this development. However there is some concern regarding the production of toxic gases should these insulation materials burn in an underground fire.

Reliable operating brake systems as well as emergency and parking brakes have been developed.

Other common safety devices available on recent equipment include:

- engine off power steering
- engine overspeed controls
- methane monitors
- automatic fire extinguisher system
- "dead man" controls
- fire resistant hydraulic fluids
- intrinsically safe electrical control systems and explosion proof fittings
- safety shut down systems
- anti-static tires
- safer diesel fuels and fuel tanks

Costs

The vehicles have high initial capital costs and require large roadways for safe operations. Diesel powered vehicles require large volumes of ventilation air to dilute exhaust gases and to prevent overheating of both the equipment and the atmosphere. Highly skilled maintenance crews are required to maintain diesel equipment in a safe and efficient operating condition. These high costs may be partially offset by lower costs for roadway surfacing, which if necessary at all is generally cheaper than laying track, and the very high productivity and versatility of FSV equipment.

Status of Evolution

There is a steadily increasing demand for four wheel drive rubber tired FSV's for use in underground mines. Present developments are directed at providing more versatile equipment for specialized applications and improving efficiency of the vehicles. Some efforts are being concentrated on use of modular components and interchangeable attachments.

A portable instrumentation package has been developed to monitor the loading of diesel engines during their underground work cycle. The results can be used to improve the design of engine/vehicle combinations.

At the Grangesburg mine in Sweden diesel powered FSV's have been modified by fitting exhaust movers. The engine fan is used to dilute and blow the exhaust gases out behind the vehicle. The fan is sufficiently powerful to blow the fumes up to 40 m out of a poorly ventilated development into main haulage roads where they are rapidly diluted.

There is considerable interest in the further development of FSV transport for men and materials in coal mines using the longwall technique and to provide flexible coal or waste haulage in development headings. The trackless transport of men and materials is the subject of a technical investigation by the Mining Technology Clearing House of IEA Coal Research. Extensive trials with trackless personnel carriers and supply vehicles are now being made in the U.K coal industry.

A Swedish equipment company has developed a trolley powered haul-dump FSV. Eimco has developed a trolley track system and a cable hanger system for electrically powered mining machines.

FSV units in the U.K. are being redesigned with the intention of ensuring the vehicles will operate effectively in the low headroom and narrow confines of most British coal mines, as well as ensuring flameproofing requirements are satisfied.

Some coal mines in Canada have introduced FSV units, the principal purpose generally being to supplement existing track systems and support personnel and materials transport.

Suppliers

A partial list of suppliers of FSV equipment is provided in Table 4.3. Their addresses appear in Appendix B-2.

FSV - Small - Golf Cart - Battery

Principal service		Personnel
Seating capacity		1-2
Steering configuration		Front wheel
Driver position		Front facing
Engine type		36V DC
(kW)		2
Transmission		Direct drive
Brakes - service		Hydraulic & disc on drive line
- emergency		None
- parking		Mechanical
Drive		Rear wheel
Maximum Speed (km/h)		13
Gradeability		Practical limit 10°
Dimensions (cm)	length	300
	width	150
	height	90
	wheel base	220
	ground clearance	20
Turning radius (cm)	inside	Not specified
	outside	Not specified
Weight (kg) -	empty	800
-	payload	700
Tire Size -	front	18 x 9.50 x 8
-	rear	18 x 9.50 x 8
Stability		Good
Safety		Fair
Acceptability		Accepted
Roadway requirements		No special requirements but performance and maintenance costs will vary with floor conditions.
Ventilation requirements		No special requirements.
Cost - initial		$11,000
- maintenance		Medium
Certification		Permissible in U.S. (not certified for use in Canadian coal mines).
Statutory requirements		Specific limitations
Case history		Preston Energy, West Virginia
Typical Manufacturer		Memco HV150-2

FSV - Small - Load Haul Dump - Diesel

Principal service		Production
Seating capacity		1
Steering configuration		Articulated
Driver position		Center, side facing
Engine type		Deutz F4L 912W
(kW)		49
Transmission		Automatic
Brakes - service		FW & RW hydraulic
- emergency		-
- parking		Mechanical on drive line
Drive		4 wheel
Maximum Speed (km/h)		18
Gradeability		Max. 14° (See performance curves)
Dimensions (cm)	length	230
	width	125
	height	120
	wheel base	250
	ground clearance	Not specified
Turning radius (cm)	inside	250
	outside	420
Weight (kg) -	empty	5600
-	payload	2400
Tire Size -	front	9.5 x 20
-	rear	9.5 x 20
Stability		Good
Safety		Good
Acceptability		Accepted (used in U/G metal mines).
Roadway requirements		Can operate on natural floors but performance and maintenance depends upon floor conditions.
Ventilation requirements		Specific requirements.
Cost - initial		$73,000
- maintenance		High
Certification		Not permissible (not certified for use in Canadian coal mines).
Statutory requirements		N.A.
Case history		Windsor, Ontario
Typical Manufacturer		Schopf L62

FSV - Small - Load Haul Dump - Electric

Principal service		Production
Seating capacity		1
Steering configuration		Articulated
Driver position		Center, front facing
Engine type		3 phase 460/575 v A.C.
(kW)		30
Transmission		Hydrostatic
Brakes	- service	4 wheel, hydraulic
	- emergency	
	- parking	Spring applied, disc
Drive		4 wheel drive
Maximum Speed (km/h)		9.7
Gradeability		Max. 15^{o} (See performance curves)
Dimensions (cm)	length	555
	width	120
	height	155
	wheel base	190
	ground clearance	20
Turning radius (cm)	inside	210
	outside	350
Weight (kg)	- empty	5900
	- payload	6500
Tire Size	- front	9 x 20
	- rear	9 x 20
Stability		Good
Safety		Fair
Acceptability		Innovative (limited distance capability).
Roadway requirements		Performance and maintenance costs will vary with floor conditions.
Ventilation requirements		No specific requirements.
Cost	- initial	$110,000
	- maintenance	Medium
Certification		Not permissible (not certified for use in Canadian coal mines).
Statutory requirements		N.A.
Case history		Asarco, Leadville, Colorado
Typical Manufacturer		Wagner EHST-1A

FSV - Small - Tractor - Diesel

Principal service		Personnel
Seating capacity		1-5 (configuration to suit customer)
Steering configuration		Front wheel
Driver position		Center front facing
Engine type		Diesel 3 or 4 cy
(kW)		8
Transmission		8 speed manual
Brakes - service		Internal wet disc
- emergency		Spring applied hydraulic
- parking		Parking brake rod
Drive		4 wheel
Maximum Speed (km/h)		12
Gradeability		Practical limit 14°
Dimensions (cm)	length	180
	width	110
	height	110
	wheel base	120
	ground clearance	25
Turning radius (cm)	inside	Not specified
	outside	Not specified
Weight (kg) -	empty	400
-	payload	Not rated
Tire Size -	front	20 x 8 x 8.00-10
-	rear	27 x 8.5 - 15
Stability		Fair
Safety		Fair
Acceptability		Accepted (used in US metal mines).
Roadway requirements		No special requirement but performance and maintenance costs will vary with floor conditions.
Ventilation requirements		Specific requirements dependent on HP and exhaust emissions.
Cost - initial		$25,000
- maintenance		Medium
Certification		U.S. Sched. 24 (not certified in Canadian coal mines).
Statutory requirements		Specific limitations.
Case history		Dennison Mines, Elliot Lake, Ontario
Typical Manufacturer		Miltor PC5K

FSV - Small - Truck - Battery

Principal service		Personnel
Seating capacity		1-2
Steering configuration		Direct drive
Driver position		Center, side facing
Engine type		72 V DC
(kW)		11
Transmission		-
Brakes - service		Disc and caliper
- emergency		Disc and caliper
- parking		None
Drive		4 wheel
Maximum Speed (km/h)		20
Gradeability		Practical limit 14°
Dimensions (cm)	length	400
	width	190
	height	70
	wheel base	320
	ground clearance	25
Turning radius (cm)	inside	Not rated
	outside	540
Weight (kg) -	empty	2000
-	payload	900
Tire Size -	front	6.50 x 10
-	rear	6.50 x 10
Stability		Good
Safety		Good
Acceptability		Accepted
Roadway requirements		No special requirements, performance and maintenance cost will vary with floor conditions.
Ventilation requirements		No specific requirements.
Cost - initial		$28,000
- maintenance		Medium
Certification		Permissible in US (not certified for use in Canadian coal mines).
Statutory requirements		Specific limitations.
Case history		Taggert Coal, Buckhannon, West Virginia
Typical Manufacturer		WMC 1500

FSV - Small - Truck - Diesel

Principal service		Material/Personnel
Seating capacity		1-4
Steering configuration		Front wheel
Driver position		Forward, front facing
Engine type		4 cy diesel (Deutz or Nissan)
(kW)		63
Transmission		4 speed manual or automatic
Brakes - service		Power
- emergency		-
- parking		Lever
Drive		4 wheel
Maximum Speed (km/h)		Up to 80
Gradeability		Practical limitation 14°
Dimensions (cm)	length	400
	width	170
	height	195
	wheel base	230
	ground clearance	30
Turning radius (cm)	inside	Not specified
	outside	Not specified
Weight (kg)	- empty	1770
	- payload	900
Tire Size	- front	750 x 16
	- rear	750 x 16
Stability		Good
Safety		Good
Acceptability		In metal mines.
Roadway requirements		No special requirements but maintenance and performance vary with floor conditions.
Ventilation requirements		Specific requirements.
Cost - initial		$15,000
- maintenance		High
Certification		Certified in Canada for metal mining only (not certified for use in Canadian coal mines).
Statutory requirements		Specific limitations.
Case history		Allen Potash Mines, Saskatchewan
Typical Manufacturer		Toyota FJ45 F/B

FSV - Medium - Bus - Diesel

Principal service		Personnel
Seating capacity		1-18
Steering configuration		4 wheel
Driver position		Front facing, either end
Engine type		Becoritt MWM diesel
(kW)		40
Transmission		Powershift
Brakes - service		Disc hydraulic, all wheel
- emergency		Spring applied hydraulic release on drive line
- parking		Spring applied hydraulic release on drive line
Drive		4 wheel
Maximum Speed (km/h)		20
Gradeability		Practical limit 14°
Dimensions (cm)	length	670
	width	210
	height	170
	wheel base	330
	ground clearance	30
Turning radius (cm)	inside	160
	outside	450
Weight (kg)	- empty	5600
	- payload	1800
Tire Size	- front	8.25 x 15
	- rear	8.25 x 15
Stability		Good
Safety		Good
Acceptability		Innovative
Roadway requirements		Can operate on natural floors but floor conditions will affect performance and maintenance.
Ventilation requirements		Specific limitations (SMRE Buxton Design).
Cost - initial		Under development.
- maintenance		High
Certification		Designed for use in U/G coal mines.
Statutory requirements		Specific limitations.
Case history		Iscor, South Africa
Typical Manufacturer		Dosco - Bus

FSV - Medium - Golf Cart - Battery

Principal service	Personnel
Seating capacity	1-8
Steering configuration	Front wheel
Driver position	Forward front facing

Engine type	36 volt DC
(kW)	4
Transmission	Direct drive
Brakes - service	All wheels hydraulic
- emergency	None
- parking	Mechanical on rear wheels
Drive	V belt drive

Maximum Speed (km/h)		21
Gradeability		Practical limit 10°
Dimensions (cm)	length	310
	width	125
	height	110
	wheel base	185
	ground clearance	15
Turning radius (cm)	inside	245
	outside	730
Weight (kg)	- empty	650
	- payload	900
Tire Size	- front	5.70 x 8
	- rear	5.70 x 8

Stability	Good
Safety	Fair
Acceptability	Problematic
Roadway requirements	No special requirements but floor conditions will affect performance and maintenance costs.
Ventilation requirements	No special requirements.

Cost - initial	$6,500
- maintenance	Low

Certification	Permissible (not certified for use in Canadian mines).
Statutory requirements	Specific limitations.

Case history	Used but no examples given.
Typical Manufacturer	Cushman 339

FSV - Medium - Load Haul Dump - Battery

Principal service		Personnel
Seating capacity		1-8 men
Steering configuration		Articulated
Driver position		Center, side facing
Engine type		128 volts DC
(kW)		Not rated
Transmission		-
Brakes - service		Pressure applied (foot) dual piston
- emergency		-
- parking		Lever lock-manually applied
Drive		4 wheel
Maximum Speed (km/h)		9
Gradeability		Practical limit 14°
Dimensions (cm)	length	800
	width	280
	height	85
	wheel base	350
	ground clearance	30
Turning radius (cm)	inside	Not specified
	outside	Not specified
Weight (kg)	- empty	9300
	- payload	Not rated
Tire Size	- front	14.50 x 15
	- rear	14.50 x 15
Stability		Good
Safety		Good
Acceptability		Accepted
Roadway requirements		No special requirements but performance and maintenance varies with floor conditions.
Ventilation requirements		No special requirements.
Cost - initial		$115,000
- maintenance		Medium
Certification		US Schedule 31 (certifiable for use in Canadian coal mines).
Statutory requirements		Specific limitations.
Case history		Emergy Mining, Huntington, Utah
Typical Manufacturer		S & S 488

FSV - Medium - Load Haul Dump - Battery

Principal service		Material/Production
Seating capacity		1
Steering configuration		Articulated
Driver position		Center, front facing
Engine type		120 volt DC series
(kW)		Not rated
Transmission		1 speed
Brakes - service		Hydraulic disc
- emergency		-
- parking		Lever
Drive		4 wheel
Maximum Speed (km/h)		8
Gradeability		Practical limit 15°
Dimensions (cm)	length	850
	width	245
	height	90
	wheel base	370
	ground clearance	25
Turning radius (cm)	inside	430
	outside	740
Weight (kg)	- empty	16,000
	- payload	5,000
Tire Size	- front	14.5 x 15
	- rear	14.5 x 15
Stability		Excellent
Safety		Fair
Acceptability		Accepted widely.
Roadway requirements		Require fairly good roadway due to low ground clearance.
Ventilation requirements		No special requirements.
Cost - initial		$150,000
- maintenance		Medium
Certification		Permitted (certified for use in Canadian coal mines).
Statutory requirements		No special limitations.
Case history		Consol, Moundsville, West Virginia
Typical Manufacturer		Eimco-Elkhorn 580

FSV - Medium - Load Haul Dump - Diesel

Principal service		Material/Production/ Personnel
Seating capacity		1-15
Steering configuration		Articulated
Driver position		Center, side facing
Engine type		Cat 3304 NA or Deutz F6L413W
(kW)		72
Transmission		3 speed automatic
Brakes - service		Disc-all wheels
- emergency		-
- parking		Spring applied disc on transmission
Drive		All wheel
Maximum Speed (km/h)		16 (See performance chart)
Gradeability		Practical limit 15°
Dimensions (cm)	length	790
	width	195
	height	165
	wheel base	290
	ground clearance	20
Turning radius (cm)	inside	260
	outside	520
Weight (kg)	- empty	14,500
	- payload	5,500
Tire Size	- front	17.5 x 25
	- rear	17.5 x 25
Stability		Good
Safety		Good
Acceptability		Accepted
Roadway requirements		No specific requirements but performance and maintenance costs will vary with road conditions.
Ventilation requirements		Special requirements dependent upon HP and exhaust emission.
Cost - initial		$175,000
- maintenance		High
Certification		US Schedule 31 (certifiable for use in Canadian coal mines).
Statutory requirements		Specific limitations.
Case history		Emery Mining, Huntington, Utah
Typical Manufacturer		Eimco 913-31

FSV - Medium - Load Haul Dump - Electric

Principal service		Personnel
Seating capacity		1-15-20
Steering configuration		Articulated
Driver position		Center, side facing
Engine type		Electric 575 VAC (cable reel)
(kW)		130
Transmission		4 speed
Brakes - service		4 wheel hydraulic disc
- emergency		-
- parking		Spring applied air released
Drive		4 wheel
Maximum Speed (km/h)		9.6 (see performance curves)
Gradeability		Practical limit 14°
Dimensions (cm)	length	940
	width	220
	height	220
	wheel base	330
	ground clearance	Not specified
Turning radius (cm)	inside	350
	outside	640
Weight (kg) -	empty	21,300
-	payload	6,800
Tire Size -	front	18.00 x 25
-	rear	18.00 x 25
Stability		Good
Safety		Good
Acceptability		Innovative (distance limitation).
Roadway requirements		No special requirements but performance and maintenance cost will vary with conditions.
Ventilation requirements		No special requirements.
Cost - initial		$310,000
- maintenance		Medium
Certification		Not permissible.
Statutory requirements		N.A.
Case history		None cited
Typical Manufacturer		Wagner EST-5B

FSV - Medium - Load Haul Dump - Electric

Principal service		Material/Production
Seating capacity		1
Steering configuration		Articulated
Driver position		Center, side facing
Engine type		1000 v Siemans
(kW)		132
Transmission		2 gear full power shift
Brakes - service		4 wheel, 2 circuit fail safe air
- emergency		-
- parking		Air on all wheels
Drive		4 wheel
Maximum Speed (km/h)		14
Gradeability		Practical limit 15°
Dimensions (cm)	length	950
	width	250
	height	190
	wheel base	365
	ground clearance	50
Turning radius (cm)	inside	460
	outside	740
Weight (kg)	- empty	21,500
	- payload	9,000
Tire Size	- front	16 x 25
	- rear	16 x 25
Stability		Good
Safety		Fair
Acceptability		Accepted (distance limitations.
Roadway requirements		No specific requirements but performance and maintenance costs will vary with floor conditions.
Ventilation requirements		No special requirements.
Cost - initial		$112,000
- maintenance		Medium
Certification		Permissible (certified for use in Canadian coal mines).
Statutory requirements		N.A.
Case history		Wolf Mountain, British Columbia
Typical Manufacturer		Schopf L110E

FSV - Medium - Shuttle Car - Electric

Principal service		Production
Seating capacity		1
Steering configuration		4 wheel-hydraulic steering
Driver position		Front facing forward
Engine type		(2) traction motors, 250 V DC
(kW)		37
Transmission		3 speed power shift
Brakes - service		4 wheel disc (drive shaft)
- emergency		Automatic
- parking		Automatic
Drive		4 wheel
Maximum Speed (km/h)		7.2
Gradeability		Practical limit14°
Dimensions (cm)	length	890
	width	340
	height	210
	wheel base	260
	ground clearance	40
Turning radius (cm)	inside	250
	outside	Not specified
Weight (kg) -	empty	29,000
-	payload	11,000
Tire Size -	front	16 x 25
-	rear	16 x 25
Stability		Good
Safety		Good
Acceptability		Acceptable (Distance limitations).
Roadway requirements		None specific, but roadway conditions influence production and maintenance costs.
Ventilation requirements		No specific requirements.
Cost - initial		$350,000
- maintenance		Low
Certification		Permissible (certified for use in Canadian coal mines).
Statutory requirements		Some limitations.
Case history		Smoky River Coal, Grande Cache, Alberta
Typical Manufacturer		Joy 10SC22-D

FSV - Medium - Tractor - Battery

Principal service		Personnel
Seating capacity		1 + 15-20 in trailer
Steering configuration		4 wheel
Driver position		Rear, side facing
Engine type		96 - 128 V DC Tram motors
(kW)		30
Transmission		Gear reducer
Brakes - service		Hydraulic
- emergency		Fail safe (spring loaded)
- parking		Level lock (hydraulic)
Drive		4 wheel
Maximum Speed (km/h)		7
Gradeability		Practical limit 14°
Dimensions (cm)	length	300
	width	240
	height	140
	wheel base	180
	ground clearance	28
Turning radius (cm)	inside	345
	outside	550
Weight (kg) -	empty	10,000
-	payload	Draw bar pull 7000
Tire Size -	front	7.50 x 15
-	rear	8.25 x 15
Stability		Good
Safety		Good
Acceptability		Accepted
Roadway requirements		No special requirement but performance and maintenance cost will vary with floor conditions.
Ventilation requirements		No specific requirements.
Cost - initial		$80,000
- maintenance		Medium
Certification		Permissible (not certified for use in Canadian coal mines).
Statutory requirements		Specific limitations.
Case history		Amax Coal, Keensburg, Illinois
Typical Manufacturer		Kersey P1144

FSV - Medium - Tractor - Diesel

Principal service		Material
Seating capacity		1
Steering configuration		Front wheel drive
Driver position		Rear center, front facing
Engine type		4 cy diesel
(kW)		60
Transmission		Manual
Brakes	- service	Hydraulic all wheel
	- emergency	-
	- parking	Lever
Drive		4 wheel
Maximum Speed (km/h)		28.6 (see chart)
Gradeability		Practical limit 14°
Dimensions (cm)	length	390
	width	200
	height	240
	wheel base	230
	ground clearance	40
Turning radius (cm)	inside	Not specified
	outside	340
Weight (kg)	- empty	3080
	- payload	Not rated
Tire Size	- front	10-24
	- rear	15-30
Stability		Fair
Safety		Fair
Acceptability		Accepted (used in U/G metal mines).
Roadway requirements		None, but floor conditions will influence maintenance and production costs.
Ventilation requirements		Specific limitations.
Cost	- initial	$41,000
	- maintenance	Medium
Certification		Not permissible (not certified for use in Canadian coal mines).
Statutory requirements		N.A.
Case history		Dennison Mines, Elliot Lake, Ontario
Typical Manufacturer		Kubota M7950DT

FSV - Medium - Truck - Battery

Principal service		Personnel
Seating capacity		1-6
Steering configuration		Direct drive
Driver position		Front facing, forward
Engine type		48 v DC
(kW)		8
Transmission		Automatic
Brakes - service		Disc
- emergency		-
- parking		Disc
Drive		Rear wheel
Maximum Speed (km/h)		20
Gradeability		Practical limit 10°
Dimensions (cm)	length	340
	width	150
	height	90
	wheel base	250
	ground clearance	25
Turning radius (cm)	inside	Not specified
	outside	Not specified
Weight (kg) -	empty	1000
-	payload	950
Tire Size -	front	6.50 x 10
-	rear	6.50 x 10
Stability		Good
Safety		Fair
Acceptability		Accepted
Roadway requirements		No special requirements but performance and maintenance will depend on conditions.
Ventilation requirements		No specific requirements.
Cost - initial		$13,800
- maintenance		Medium
Certification		Permissible in US (not certified for use in Canadian coal mines).
Statutory requirements		Specific limitations.
Case history		Marion Fuels, West Virginia
Typical Manufacturer		WMC 500

FSV - Medium - Truck - Diesel

Principal service		Personnel
Seating capacity		1-12
Steering configuration		Power
Driver position		Forward, front facing
Engine type		4 cy Diesel
(kW)		43
Transmission		4 speed
Brakes - service		Wet disc
- emergency		Fail safe spring applied
- parking		Fail safe spring applied
Drive		4 wheel
Maximum Speed (km/h)		17
Gradeability		Practical limit 14°
Dimensions (cm)	length	380
	width	185
	height	200
	wheel base	200
	ground clearance	25
Turning radius (cm)	inside	Not specified
	outside	500
Weight (kg) -	empty	2700
-	payload	1800
Tire Size -	front	7.50 x 10
-	rear	7.50 x 10
Stability		Fair
Safety		Fair
Acceptability		Accepted (used in U/G metal mines).
Roadway requirements		No special requirements but performance and maintenance depends on roadway conditions.
Ventilation requirements		Special requirements.
Cost - initial		$45,000
- maintenance		High
Certification		Not permissible (not certified for use in Canadian coal mines).
Statutory requirements		N.A.
Case history		Tanco, Masco, Bervice Lake
Typical Manufacturer		Teledyne TMP5

FSV - Medium - Truck - Diesel Articulated

Principal service		Personnel
Seating capacity		1-15
Steering configuration		Articulated
Driver position		Front, forward facing
Engine type		Diesel (Deutz) 6 cy
(kW)		60
Transmission		4 speed
Brakes - service		Hydraulic dry disc
- emergency		Spring applied
- parking		-
Drive		4 wheel drive
Maximum Speed (km/h)		10
Gradeability		Practical limit 14°
Dimensions (cm)	length	680
	width	250
	height	225
	wheel base	350
	ground clearance	38
Turning radius (cm)	inside	370
	outside	640
Weight (kg) -	empty	7,300
-	payload	11,000
Tire Size -	front	10 x 20
-	rear	10 x 20
Stability		Fair
Safety		Good
Acceptability		Accepted (Used in U/G metal mines).
Roadway requirements		No special requirements but performance and maintenance will vary with road conditions.
Ventilation requirements		Require specific ventilation depending on HP and exhaust emissions.
Cost - initial		$75,000
- maintenance		High
Certification		Not permissible (not certified for use in Canadian coal mines).
Statutory requirements		N.A.
Case history		Dennison Mines, Elliot Lake, Ontario
Typical Manufacturer		Miltor PC15M

FSV - Large - Bus - Diesel

Principal service		Personnel
Seating capacity		1-55
Steering configuration		Power
Driver position		Front, facing forward
Engine type		Cat 3208 diesel
(kW)		160
Transmission		Automatic
Brakes - service		Full air system
- emergency		Spring brake
- parking		Dash mounted valve
Drive		2 wheel
Maximum Speed (km/h)		Will vary with function
Gradeability		Practical limit 10°
Dimensions (cm)	length	1200
	width	250
	height	300
	wheel base	625
	ground clearance	30
Turning radius (cm)	inside	Not specified
	outside	1350
Weight (kg) -	empty	9000
-	payload	3600
Tire Size -	front	11 x 22.5
-	rear	11 x 22.5
Stability		Good
Safety		Good
Acceptability		Accepted
Roadway requirements		Can operate on natural floors but for satisfactory operation require prepared roadways.
Ventilation requirements		Specific requirements dependent upon HP and exhaust emissions.
Cost - initial		$75,000
- maintenance		High
Certification		Not permissible (not certified for use in Canadian mines)
Statutory requirements		N.A.
Case history		Uranium City, Saskatchewan
Typical Manufacturer		Blue Bird

FSV - Large - Load Haul Dump - Diesel

Principal service		Material/Production
Seating capacity		1
Steering configuration		Articulated
Driver position		Center, side facing
Engine type		Cat diesel 3406TA
(kW)		260
Transmission		4 speed powershift
Brakes - service		4 wheel disc
- emergency		-
- parking		Spring applied drive line
Drive		4 wheel
Maximum Speed (km/h)		24 (See performance curve)
Gradeability		Manufacturer recommends not to exceed 27°
Dimensions (cm)	length	1150
	width	305
	height	260
	wheel base	430
	ground clearance	40
Turning radius (cm)	inside	365
	outside	760
Weight (kg)	- empty	46,000
	- payload	18,000
Tire Size	- front	29.5 x 29
	- rear	29.5 x 29
Stability		Good
Safety		Good
Acceptability		Widely used in U/G metal mines.
Roadway requirements		Can operate on natural floors but performance and maintenance costs depend on roadway conditions.
Ventilation requirements		Specific requirements. (MSHA 1560 m^3/min).
Cost - initial		$525,000
- maintenance		High
Certification		US Schedule 31 (not certified for use in Canadian coal mines).
Statutory requirements		Specific limitations.
Case history		Cargill Salt, Belle Isle, Louisiana
Typical Manufacturer		Wagner Scooptram ST-13S

FSV - Large - Load Haul Dump - Electric

Principal service		Material/Production
Seating capacity		1
Steering configuration		Articulated
Driver position		Center, side facing
Engine type		Electric 3 phase 660 VAC (other voltages available)
(kW)		150
Transmission		4 speed powershift
Brakes - service		4 wheel disc
- emergency		-
- parking		Spring applied drive line
Drive		4 wheel
Maximum Speed (km/h)		9.6
Gradeability		(See performance curves)
Dimensions (cm)	length	1070
	width	250
	height	220
	wheel base	350
	ground clearance	30
Turning radius (cm)	inside	325
	outside	670
Weight (kg) -	empty	8,000
-	payload	11,000
Tire Size -	front	26.5 x 25
-	rear	26.5 x 25
Stability		Good
Safety		Good
Acceptability		Accepted (distance limitations).
Roadway requirements		Can operate on natural floors but performance and maintenance costs will vary with roadway conditions.
Ventilation requirements		No special requirements.
Cost - initial		$360,000
- maintenance		Medium
Certification		Not permissible (not certified for use in Canadian coal mines).
Statutory requirements		N.A.
Case history		None cited
Typical Manufacturer		Wagner Scooptram EST-8A

FSV - Large - Truck - Diesel

Principal service		Personnel
Seating capacity		1-40
Steering configuration		4 wheel
Driver position		Front, foward facing
Engine type		3208 Cat diesel V8
(kW)		90
Transmission		4 speed powershift
Brakes - service		Spring applied - air released
- emergency		Hand operated spring applied air released
- parking		Hand operated spring applied air released
Drive		4 wheel
Maximum Speed (km/h)		20
Gradeability		Practical limit 14°
Dimensions (cm)	length	680
	width	250
	height	240
	wheel base	460
	ground clearance	30
Turning radius (cm)	inside	Not specified
	outside	Not specified
Weight (kg)	- empty	5000
	- payload	5000
Tire Size	- front	10 x 20
	- rear	10 x 20
Stability		Good
Safety		Good
Acceptability		Accepted (used in U/G metal mines).
Roadway requirements		Can operate on natural floors but performance and maintenance costs will depend on floor conditions.
Ventilation requirements		Specific requirements.
Cost - initial		$120,000
- maintenance		High
Certification		Not permissible (not certified for use in Canadian coal mines).
Statutory requirements		N.A.
Case history		Cominco, Kimberley, British Columbia
Typical Manufacturer		Teledyne TMP10

FSV - Large - Truck - Diesel Articulated

Principal service		Personnel
Seating capacity		1-33
Steering configuration		Articulated
Driver position		Center, forward facing
Engine type		Diesel GM 6V71
(kW)		138
Transmission		Power shift
Brakes - service		Dual disc
- emergency		-
- parking		Drive line
Drive		4 wheel
Maximum Speed (km/h)		31
Gradeability		Rated at 10° at 31 km/hr, max. up to 16° at 4.8 km/h
Dimensions (cm)	length	820
	width	280
	height	170
	wheel base	490
	ground clearance	35
Turning radius (cm)	inside	500
	outside	830
Weight (kg)	- empty	13,000
	- payload	17,000
Tire Size	- front	12.00 x 25
	- rear	12.00 x 25
Stability		Good
Safety		Good
Acceptability		Accepted (used in U/G metal mines).
Roadway requirements		Can operate on natural floors but performance and maintenance costs will depend on floor conditions.
Ventilation requirements		Specific requirements.
Cost - initial		$172,000
- maintenance		High
Certification		Not permissible (not certified for use in Canadian coal mines).
Statutory requirements		N.A.
Case history		Dennison Mines, Elliot Lake, Ontario
Typical Manufacturer		Dux DCA-32

FSV - Large - Truck - Diesel Articulated

Principal service		Production
Seating capacity		1
Steering configuration		Articulated
Driver position		Forward, front facing
Engine type		Diesel 6 cy CAT 3306TA
(kW)		194
Transmission		6 speed powershift
Brakes - service		Air over hydraulic (all wheel) foot operated
- emergency		-
- parking		Fail safe spring applied
Drive		4 wheel
Maximum Speed (km/h)		50
Gradeability		Practical limit 15°
Dimensions (cm)	length	920
	width	330
	height	330
	wheel base	490
	ground clearance	60
Turning radius (cm)	inside	740
	outside	1600
Weight (kg) -	empty	20,500
-	payload	32,000
Tire Size -	front	26.5 x 25
-	rear	33.25 x 29
Stability		Good
Safety		Good
Acceptability		Accepted for severe transport conditions.
Roadway requirements		Can operate on natural floors but performance and maintenance costs will depend on roadway conditions.
Ventilation requirements		Specific limitations.
Cost - initial		$300,000
- maintenance		High
Certification		Not permissible (not certified for use in Canadian coal mines)
Statutory requirements		N.A.
Case history		Syncrude, Ft. McMurray, Alberta
Typical Manufacturer		DJB D35C

4.5 CONVEYORS

Historical Development

Belt conveyors were first introduced as a major transport system in underground mines with the advent of mechanized longwall mining techniques in the early 1950's when there was a determined move away from ropes and tubs for mineral haulage to trunk conveying systems.

Following the introduction of fire resistant belts, high tension strength belts and improved drive design, more rapid progress has been made.

Conveyor Assemblies

The conventional belt conveyor consists of the support structure, rollers, the belt, the drive and the tensioning equipment.

The supporting structure can be either floor mounted or suspended from the roof of an underground roadway.

Belting types presently used in underground mining are either synthetic fibre belts, steel cord belts or cable belts. The first two types require similar supporting structures with conventional belt rollers. In the cable belt system the entire weight of the belt is supported by a pair of steel ropes which run over pulleys below the belt.

The drive for modern high capacity conveyors is typically electric with a hydrokinetic coupling (which allows smooth starting) to a gearbox and the drive drum or pulley.

Manriding by Belt Conveyors - Status and Developments

The main advantages of conveyor manriding over other systems are:

- Little additional equipment is required where conveyors are in use for mineral transport.
- It provides a means of continuously available transport with significant reduction in waiting time.
- Can be used where the installation of other means of manriding is prohibited.
- Men are transported individually, which reduces the hazard associated with crowding at manriding stations.

Outbye manriding is in common use in mining, primarily because men are travelling in the normal conveyor direction, inbye manriding is less common. Use of reversible conveyors and manriding on the bottom belt allows free movement either way. Boarding and alighting the conveyor are the critical points in personnel conveying safety. Manriding speeds on conveyors are often controlled.

Regulations in different countries limit the manriding speed to 2.13 m/s (U.K.) 2.67 m/s (South Africa) 2.5 m/s (FRG). Experiments (in Bergau Forschung, FRG) showed that miners familiar with manriding by belt conveyors were capable of boarding and alighting safely at speeds of 4 m/s.

There have been extensive investigations and engineering studies into the development of safer devices for transfer to and from high speed conveyors. The use of accelerating and decelerating conveyors permitting transfer at near zero speed differential to the main manriding belt is an interesting development.

Material Transport by Belt Conveyors

Only light materials can be transported on the belt of conventional conveyors. Materials can be transported inbye on the bottom belt at the same time as coal is being carried outbye. The size of materials transported is restricted by the distance between the top and bottom belts, which depends on the conveyor structure. A minimum clearance is necessary for the transport of long materials, such as girders, over slight variations in belt gradient without fouling the top belt. Loading and unloading materials on the bottom belt requires a good organization. Special rollers may be necessary to support the bottom belt on conveyors used for carrying materials. Materials can be carried inbye on the top belt of a reversible conveyor during periods when minerals are not being carried.

The transport of heavy and bulky loads is not practical. A British manufacturer has developed a type of material trolley which is mounted onto the conveyor belt structure and can be either belt powered or hauled with an independent rope haulage. This system allows the conveyor structure to be put in the centre of a roadway where there is greater clearance and where it should be less affected by floor heave. One disadvantage of this type of trolley is that it can only be used when the belt is empty. These trolleys are intended for use in development headings for retreat longwall faces where they can be used to transport supplies to the development for the transport of face equipment and for the salvage of support materials as the face retreats.

Safety

Safety aspects of manriding and material transport on belt conveyors is mainly concerned with transfers onto and off of the system.

Fire resistant belts when exposed to friction of non-moving parts i.e. misaligned belt rubbing on parts of support construction, or on seized rollers, create dust and scraps which may be susceptible to ignition. Conveyor belts require substantial maintenance expenditures to ensure that they do not develop "hot spots" and that the rollers are in good order.

Safety devices such as pull cords which interrupt the operation and anti-reverse mechanisms are necessary for men and materials transport on conveyors. Training of personnel in approved procedures for use of manriding conveyors should receive high priority when they are first installed. Good illumination and clearly marked signs are also essential.

Costs

The cost of conveyor belt transport is low if the main mineral clearance system is also used for manriding. Installations required for adapting a conveyor to manriding or materials handling are not complicated and are inexpensive when compared with alternative systems.

Although easily automated for mineral transport, conveyors used for men and materials require operations manpower. Maintenance of manriding conveyors should be to the highest possible standards and will usually be more costly than for non-manriding installations.

Suppliers

A partial list of manufacturers of conveyors is provided in Table 4.4. Their addresses appear in Appendix B-2.

4.6 MISCELLANEOUS TRANSPORTATION SYSTEMS

Non-conventional means of transport include man riding in buckets of LHD equipment and in cars intended for mineral conveyance.

Handgrips welded to the walls of shuttle cars or outside buckets to facilitate manriding are sometimes seen. Detachable seating is frequently provided for manriding in mineral cars on RVIP systems.

Ski lift systems can be used advantageously for rapid transport of personnel particularly over steep and changing gradients. The method is not well suited to the movement of heavy materials and movement of components is labour intensive. An efficient personnel installation is operating at Rozelay Mine, Blanzy, France.

Chain lifts which are comparable to ski lifts can be used to transport men along steep roadways. One system installed at Kilbarchan Colliery in South Africa can also handle small parcels of material.

Walking belts and escalators are not used in underground coal or metal mines.

The assisted walking systems can be used in roadways of short lengths and steep gradients. The system requires an endless rope and the use of walking sticks clipped to the rope.

Raise climbers are used extensively in metal mines for transport but normally on very steep applications.

Numerous tracked vehicles have been developed and are used extensively in many special surface situations but are not used in underground coal or metal mines.

Suppliers

A partial listing of manufacturers of miscellaneous transport systems is provided in Table 4.5. Their addresses appear in Appendix B-2.

4.7 ANCILLARY TRANSPORTATION SYSTEMS

4.7.1 Definition

Ancillaries include all the equipment, devices and installations necessary to ensure efficient working of transport facilities.

Included are:

- loading, transfer, and unloading equipment
- installations and equipment for personnel boarding and alighting
- power supply equipment
- service equipment - track and roadway maintenance

4.7.2 State of the Art

Loading Equipment

With the advent of high capacity transport and high speed equipment a need for mechanization of loading has been created. Loading equipment working in underground mines has special requirements due to space limitations. Building up of exhaust gases in a stationary location imposes restrictions on the use of diesel equipment and encourages the use of electric machinery.

The following types of machines are used:

Mobile	Forklift
	LHD equipment with QDC (quickly-detachable components) fork or crane attachments
	Front end loaders
	Cranes
Stationary	specially designed cranes

- monorail winches
- swing arm cranes

Specially designed containers and modules have exercised a great impact on the speed of loading operations. Containers provide storage capacity and protection which is important for materials or equipment sensitive to humidity and dust or for the transport of explosives.

Personnel Boarding and Alighting Installations

Personnel boarding and alighting installations are normally installed to accommodate local conditions in the mine. A manriding conveyor boarding and alighting device that accelerates (or decelerates) from almost 0 to travel speed of a high speed conveyor has recently been developed.

Power Supply Equipment

This group includes substations, transformers, rectifiers and battery chargers for electric equipment and fueling stations for diesel engined machines.

Road Maintenance Equipment

Roadway conditions are a very important factor in the overall efficiency of rubber tired equipment. Graders (low profile for thin seam workings), compactors and water spray equipment are commonly in use for road maintenance.

Track maintenance and levelling machinery is also being introduced underground where high speed rail systems are in use.

Other Ancilliary Equipment

Roadway-doors which are part of the ventilation system play a critical role in the efficiency of transport systems. Automatic and remote control of doors and airlocks can speed up the passage of transportation equipment. Safe, efficient systems which maintain the required air stopping are difficult to keep in operation on major haulages and should be avoided if at all possible on high speed roadways.

Suppliers

A partial listing of manufacturers of ancilliary transport systems is provided in Table 4.6. Their addresses appear in Appendix B-2.

4.8 MONITORING AND CONTROL

Monitoring and control in underground mining is based on cable and radio communication. Radio communication is the most convenient system for use in transport due to its mobile character.

Radio waves do not propagate at practical communication frequencies through mine workings to any useful extent. The inductive loop technique which employs the transformation principle to carry a modulated signal from a specially laid conductor wire to the frame of a vehicle, is useful for monitoring and control of mobile equipment while the leaky-feeder principle is more practical as a personal means of communication.

These techniques enable efficient communication and remote control of haulage, successful dispatching and reductions in the number of personnel employed in the transport operations. Daw Mill Colliery (U.K.) has successfully applied radio control for high-speed rope hauled manriding and material transport. At Treeton Colliery (U.K.) a rope-hauled personnel train consisting of 7 cars carries a crew at a maximum speed of 22.7 km/hr over a distance of almost 3.5 km at gradients up to 11°.

The following features can be radio controlled in rail transport systems:

- voice communication
- speed control
- locking system activation from the train
- automatic brake application

Communication with free steered vehicles is possible wherever conductor wires are laid out but the application of remote control and automation is limited. There have been experiments using leading wires and radio communication for the control of free steered vehicles in roadways but at present and in the foreseeable future, remote control of FSV's, is not of major importance and voice communications are more worthwhile developments.

Monitoring and control of conveyor transport is relatively easy to realize due to stationary character of installations and the possibility of transmitting signals by cable. Monitoring and control devices such as automatic scales, loading monitors and emergency stop activators have been developed.

The use of transponders on materials vehicles to enable their location to be identified has been proposed. A microprocessor-based power memory unit to control the acceleration and retardation of a conveyor has application in the control of manriding conveyors.

Suppliers

A partial listing of manufacturers of monitoring and control systems is provided in Table 4.6. Their addresses appear in Appendix B-2.

TABLE 4.1
PARTIAL LIST OF MANUFACTURERS OF RAIL VEHICLES INTERNAL POWERED (RVIP)

Name	CAPACITY Personnel (no.) Small 1-4	CAPACITY Personnel (no.) Medium 5-20	CAPACITY Personnel (no.) Large Over 20	CAPACITY Material (T) Small Up to 1	CAPACITY Material (T) Medium 1-10	CAPACITY Material (T) Large Over 10	SPEED in km/h Slow 0-10	SPEED in km/h Medium 11-30	SPEED in km/h Fast Over 30	GRADE CONDITIONS in Degrees Flat 0-6	GRADE CONDITIONS in Degrees Medium 6-15	GRADE CONDITIONS in Degrees Steep +15	Distance Limitation 1	Distance Limitation 2	Distance Limitation 3	Distance Limitation 4	Road Way Requirement 1	Road Way Requirement 2	Road Way Requirement 3
ANF		x	x		x	x	x	x	x	x	x	x				x		x	
ASEA Inc.			x			x	x	x		x			x			x		x	
Atlas Car (Marmon Group)	x	x		x	x		x	x		x				x				x	
Brookville Locomotive Div.	x	x	x	x	x	x	x	x		x			x						
Card Equipment Co.																			
FMC of Canada Ltd.	x	x	x	x	x	x	x	x		x					x	x		x	
George Moss Pty Ltd.	x	x	x	x	x	x	x	x		x			x				x		
Goodman Equipment Corp.	x	x	x	x	x	x	x	x		x				x		x			
Gyro Mining Transport Ltd.	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x
Hawker Siddeley Group		x	x		x	x	x	x		x			x	x				x	
Hunslett		x	x		x	x	x	x		x	x	x	x	x	x	x		x	x
Jeffrey Mining Mfg.		x	x		x	x	x	x	x	x			x	x		x		x	
Material de Fonde d' Industrie																			
Muckenhaupt GmBh		x	x		x	x	x	x		x	x		x					x	x
National Mine Service Co.	x	x		x	x		x	x		x			x	x		x		x	
NEI	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	
Plymouth Locomotive Works, Inc.	x	x	x	x	x	x	x	x		x			x	x	x	x		x	
Ruhrthaler Schwartz & Dyckerhoff KG	x	x	x	x	x	x	x	x		x			x	x				x	
Scharf Co.		x			x		x	x		x	x		x	x					x
Societe Stephanoise de Constructions		x	x		x	x	x	x		x			x					x	
Stancanada Inc. (USSR)	x	x	x	x	x	x	x	x		x			x			x		x	
UMM Ltd.		x	x		x	x	x	x		x	x	x	x						x

TABLE 4.2
PARTIAL LIST OF MANUFACTURERS OF RAIL VEHICLES EXTERNAL POWERED (RVXP)

Name	CAPACITY						SPEED in km/h			GRADE CONDITIONS in Degrees			Distance Limitation				Road Way Requirement		
	Personnel (no.)			Material (T)															
	Small 1-4	Medium 5-20	Large Over 20	Small Up to 1	Medium 1-10	Large Over 10	Slow 0-10	Medium 11-30	Fast Over 30	Flat 0-6	Medium 6-15	Steep +15	1	2	3	4	1	2	3
Becorit (G.B.) Ltd.		x	x		x	x	x	x		x	x	x							x
Gyro Mining Transport Ltd.	x	x	x	x	x	x	x	x		x	x	x							x
Material de Fonde d'Industrie		x	x		x	x	x	x		x	x	x							x
Scharf Co.	x	x	x	x	x	x	x	x		x	x	x							x
Sheepbridge Equipment Ltd.		x	x		x	x	x	x		x	x	x						x	
UMM Ltd.		x	x		x	x	x	x		x	x	x						x	x

TABLE 4.3
PARTIAL LIST OF MANUFACTURERS OF FREE STEERED VEHICLES (FSV)

	CAPACITY						SPEED			GRADE CONDITIONS			Distance Limitation				Road Way Requirement		
	Personnel (no.)			Material (T)			in km/h			in Degrees									
Name	Small 1-4	Medium 5-20	Large Over 20	Small Up to 1	Medium 1-10	Large Over 10	Slow 0-10	Medium 11-30	Fast Over 30	Flat 0-6	Medium 6-15	Steep +15	1	2	3	4	1	2	3
ANF		x	x		x	x	x	x		x	x	x	x		x		x		
American Motors Corp.	x			x			x	x	x	x	x	x							
ARA (Toro)			x			x	x	x	x	x	x								
Baycar Steel Fabricators Ltd.	x	x	x	x	x	x	x	x	x	x	x	x	x				x		
British Jeffrey Diamond		x	x		x	x	x	x		x	x		x				x		
Caterpillar Tractor Co.		x	x		x	x	x	x	x	x	x	x	x				x		
Cushman	x		x		x	x		x	x				x		x		x		
Deilmann-Haniel GmbH		x			x		x	x		x	x								
Dux Machinery Corporation	x	x	x	x	x	x	x	x	x	x	x	x	x				x		
Eimco Mining Machinery	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x		
FMC of Canada Ltd.		x	x		x	x	x			x	x	x		x			x		
Ford Motor Co. of Canada	x	x	x	x	x	x	x	x		x	x								
France Loader	x	x	x	x	x	x	x	x	x	x	x	x	x				x		
GMC	x	x	x	x	x	x	x	x	x	x	x	x	x				x		
Getman Corp.		x	x		x	x	x	x		x	x	x	x				x		
Hawker Siddeley Group		x	x		x	x	x	x		x	x	x	x	x	x		x		
Hunslett		x	x		x	x	x	x		x	x	x	x				x		
Honda	x			x			x	x	x	x	x	x	x				x		
Ingersoll-Rand Mining Machinery	x	x		x	x		x	x		x	x	x	x		x		x		
Jarvis Clark Co. Ltd.		x	x		x	x	x	x		x	x		x				x		
Jeffrey Mining Mfg.		x	x		x	x	x			x	x	x	x				x		
John Deer	x	x		x	x		x	x	x	x	x	x							
Joy Manufacturing Co.		x	x		x	x	x	x		x	x	x	x			x	x		
Kaelble, Gmbh Carl		x	x		x	x	x			x	x	x	x				x		
Kersey Manufacutring Co.	x	x		x	x		x			x	x	x			x				
Kubota Tractor Canada Ltd.	x	x	x	x	x	x	x	x		x	x	x	x				x		
McJunkin Corporation	x			x			x			x	x	x			x		x		
Mercedes-Benz Canada Inc.	x	x	x	x	x	x	x	x	x	x	x	x	x				x		
Miltor Drilling Equipment Ltd.	x	x	x	x	x	x	x	x	x	x	x	x	x				x		
Minejack Mining Equipment	x	x		x	x		x	x		x	x	x	x		x		x		
Mines De Potasse D'Alsace	x	x		x	x		x	x	x	x	x	x	x				x		
Mining Transportation Co. AB			x			x	x	x	x	x	x		x			x	x		
Schopf Maschinenbau GmbH	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x		
Stancanada Inc. (USSR)		x			x		x	x	x	x	x	x	x				x		
Teledyne Canada Mining Products		x	x		x	x	x	x	x	x	x	x	x				x		
Toyota Industrial Sales	x	x		x	x		x	x	x	x	x	x	x				x		
Volvo BM AB		x	x		x	x	x	x	x	x	x	x	x				x		
Wagner Mining Equipment Co.	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x		
Wilson Manufacturing Co. Inc.	x	x		x	x		x	x		x	x	x	x		x		x		
Yamaha	x			x			x	x		x	x	x	x				x		

TABLE 4.4
PARTIAL LIST OF MANUFACTURERS OF CONVEYORS

Name	Manriding	Standard	Long Distance
Abex Corp. (Railroad Products Group)		x	
AEC Inc. (Alpine)		x	
Anderson Strathclyde PLC		x	
Babcock Mining Services		x	
BTR Limited		x	
Cable Belt Ltd.		x	x
Continental Conveyor (BF Goodrich)		x	x
Dowty Meco Ltd.		x	
Dunlop Belting Ltd.	x	x	
Eickhoff GmbH	x	x	
EMAC		x	
Fives-Cail Babcock		x	
Fletcher Sutcliffe Wilde		x	
FMC of Canada Ltd.		x	
Forano Inc.		x	
GEC Canada Ltd.		x	
Goodyear International Corp.		x	
Greengate Industrial Polymers		x	
Hawker Siddeley (Brush)		x	
Huwood Ltd.	x	x	
Industrial Exportimport, Foreign Trade Co.		x	
Jeffrey Mining Mfg. (Dresser)		x	
Joy Manufacturing		x	
Kleber Industrie		x	
Kloeckner-Becorit North America Ltd.	x	x	
Kopex, Export-Import		x	
Krampe & Co.		x	
Krupp GmbH Canada Inc.		x	x
Long Air Dox Co. (Marmon Group)	x	x	
Man (GHH) Canada Inc.		x	
Mutsui Miike Machinery Co.	x	x	
Neuhaeuser GmbH & Co.		x	
O & K Canada	x	x	
PHB Weserhuette AG		x	
Precismeca Canada Ltd.		x	
REI (Realisation Equipments Industriels)		x	x
Rexnord Canada Ltd. (Nordberg)		x	
Societe Stephanoise		x	
TBA Industrial Products		x	
Thyssen (Great Britain Ltd.)		x	
Voest Alpine AG		x	
UMM	x	x	

TABLE 4.5
PARTIAL LIST OF MANUFACTURERS OF MISCELLANEOUS TRANSPORTATION SYSTEMS

Name	Assisted Walking	Chair Lift	Escalator	Raise Climber	Tracked Vehicle	Walking Belt
Bombardier Inc.					x	
British Ropeway Engineering Co. Ltd.		x				
Canadian Foremost Ltd.					x	
Dielmann-Haniel GmbH		x				
Dopplemayer Lifts Ltd.		x				
Klockner Becorit GmbH		x				
Krampe & Co.		x				
Linden Alimak Inc.				x		
MAN Maschinen und Stahlbau			x			x
Montgomery Elevators Co. Ltd.			x			x
Orenstein & Kopple Ag Werk			x			x
Otis Elevator Co. Ltd.			x			x
PHB Weserhuette AG		x				
Riblet Tramway Co.		x				
Robbins Co. The				x		
Scharf Mashinen Fabrick GmbH	x	x				
Schindler Aufzugefabrik GmbH			x			x
Thysen Aufzuge GmbH			x			x
Westfalia Luenen		x				

TABLE 4.6
PARTIAL LIST OF MANUFACTURERS OF ANCILLIARY TRANSPORTATION SYSTEMS AND MONITORING AND CONTROL SYSTEMS

Name	Mine Cars	Track & Accessories	Hoisting Equip.	Cranes	Monitor & Control	Graders	Tires	Forklifts	Engines	Batteries	F.E.L.
ANF Industries	x										
ABEX Corp. (Railroad Products)		x									
A & K Railroad Materials Inc.		x									
Allens of Tipton Ltd.	x		x								
American Construction Equipment Group				x							
American Mine Door		x									
Anderson Strathclyde PLC		x									
Andrew Merrillees	x										
Arbel Industries	x										
ASE Inc.	x		x		x						
Atlantic Track & Turnout Co.		x									
Atlas Car (Marmon Group)	x										
Babcok Alcat						x					
Baycar Steel Fabricators Ltd.	x			x							
Bedia GmbH & Co.				x							
Bethlehem Steel Corp.		x									
Black Box Radio Controls					x						
Bridgestone Tire							x				
Canadian General Electric							x				
Canron Inc. (WABI)	x										
Card Equipment	x										
Case Co.								x			x
Caterpillar Tractor Co.								x	x		x
Champion Road Machinery						x					
Clark Equipment Co. (Bobcat)								x			x
Communication & Control Eng. Co. Ltd.		x			x						
Conspec Control Inc.					x						
Cummins Engine Co. Ltd.									x		
DAC Limited (Dacon Works)					x						
Danmer Equipment Co.	x										
Dielmann-Haniel GmbH			x		x						
Detroit Diesel Allison									x		
Difco Inc.	x										
Dipl-Ing. TH Steinfurth GmbH		x									
Door-Oliver Canada Ltd.	x										
Duesterloh GmbH G	x		x								
Dux Machinery Corp.				x				x			
Eaton Corp. Industrial			x								
Electro Life Battery Co.										x	
Eimco Mining Machinery (Fairchild)			x				x	x	x		x
Fives-Cail Babcock	x		x								
Femco Div. Gulton Ind. Inc.					x						
FMC of Canada	x			x				x			x
Ford Motor Co. of Canada								x	x		x
Foster Co.	x	x									

TABLE 4.6 (Continued)
PARTIAL LIST OF MANUFACTURERS OF ANCILLIARY TRANSPORTATION SYSTEMS AND MONITORING AND CONTROL SYSTEMS

Name	Mine Cars	Track & Accessories	Hoisting Equip.	Cranes	Monitor & Control	Graders	Tires	Forklifts	Engines	Batteries	F.E.L.
Funke & Huster					x						
GEC Canada			x								
General Battery Corp.										x	
General Motors of Canada Ltd.									x		
George Moss Pty. Ltd.	x	x									
Goodyear International							x				
Gould Manufacturing										x	
Greening Donald Co. Ltd.			x								
Grove Manufacturing				x							
Gyro Mining Transport (GMT)									x		
Hawker Sidley Group (Dosco, Noyes)	x	x	x		x			x	x	x	
Hepburn Ltd. (John T.)			x								
H.K. Porter, Inc.		x									
Hudson Ltd. (Robert)	x	x									
Huwood Ltd.					x						
Huwood Irwin Co.	x										
Industrial/Export Import Foreign Trade Co.			x								
Ingersol Rand. Mining Machinery				x							
In-Pro Corp.	x										
Isuzu Diesel North American Ltd.									x		
Jarvis Clark								x			x
John Deere Construction Equip.								x	x		x
Joy Manufacturing			x		x						
Kaelble, Gmbh Carl				x				x			
Kloechner HumboH Deutz AG									x		
Muckenhaupt GmbH Bercorit			x						x		
Krupp GmbH Canada Inc.	x		x	x							
Lake Shore Inc.	x		x								
Lead Industries										x	
Lebus International Engineers			x								
Long Airdox Co. (Marmon Group)	x										
Man (GHH) Canada Ltd.	x		x	x				x	x		x
Mannesman Demag Ltd.			x	x							
Marathon Letourneau Co.				x				x			x
Materiel de Fonde Industrie		x	x					x	x		x
Mercedes Benz Canada Inc.				x				x	x		x
Michelin Tire Corp.							x				
Mine Equipment Co.				x							
Mine Safety Appliance Co.					x						
Mitsui Miike Machinery Co.	x		x								
Mouty - Bonehill	x										
MWM Motoren-Werke Mannhein AG									x		
National Mine Service	x	x			x						
Neeham Bros & Brown Ltd.			x								
O & K Canada			x								

TABLE 4.6 (Continued)
PARTIAL LIST OF MANUFACTURERS OF ANCILLIARY TRANSPORTATION SYSTEMS AND MONITORING AND CONTROL SYSTEMS

Name	Mine Cars	Track & Accessories	Hoisting Equip.	Cranes	Monitor & Control	Graders	Tires	Forklifts	Engines	Batteries	F.E.L.
Ohio Brass Co. (Ind. Products Div.)		x			x						
Pettibone Corp.				x							
PHB Weserhvette AG			x	x							
Pikrose & Co. Ltd. (Marmon Group)			x								
Plymouth Locomotive Works					x						
Pollain			x								x
Rexnord Canada Ltd. (Norberg)			x								
Saab-Scania AB		x							x		
Safetran Systems Corp.		x			x						
Safety Supply Canada					x						
SAMIIA			x								
Sanford Day	x										
Scharf Co.	x	x	x	x	x						
Schopf								x			x
Sheepbridge Equipment Ltd.	x										
SILEC DSI					x						
Stancanada Inc. (USSR)								x			x
Strojexport, Foreign Trade Co.	x										
Teledyne Canada Mining Products				x							
Thyssen (Great Britain) Ltd.			x								
Timberland Equipment			x								
Toyo Kogyo Co. Ltd.							x		x		
UMM				x							
Voest Alpine			x					x			x
Volvo BM AB								x			x
Westinghouse Electric Corp.			x								
Wheway Watson Holdings Ltd.				x							
Wire Rope Industries			x								
Wolff Maschinenfabric GmbH Emil			x								

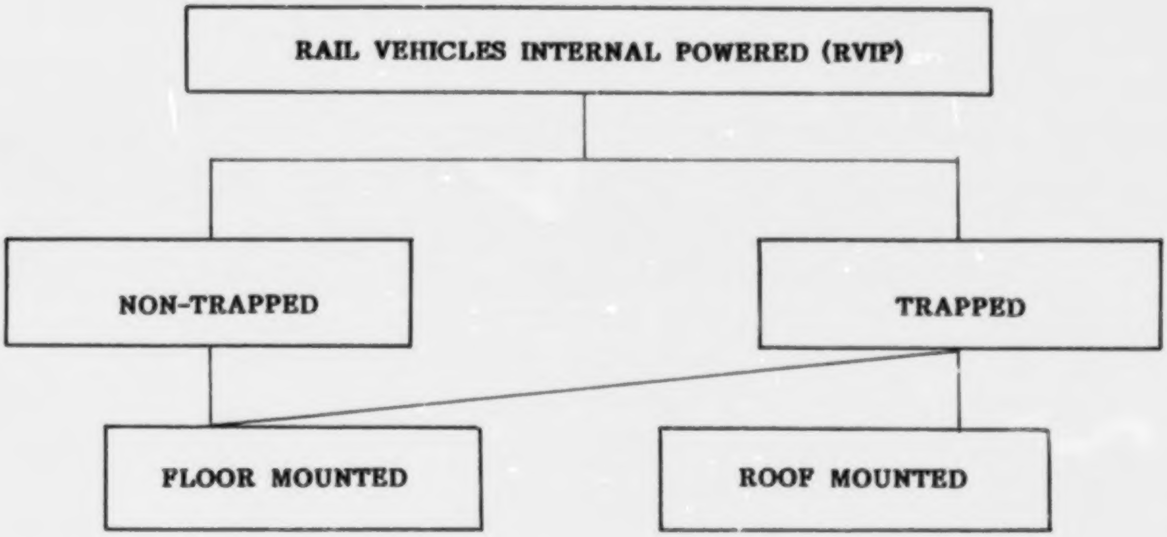

RAIL VEHICLES INTERNAL POWERED (RVIP)
NON-TRAPPED
TRAPPED
FLOOR MOUNTED
ROOF MOUNTED

FIGURE 4-1

CLASSIFICATION OF RAIL VEHICLES INTERNAL POWERED

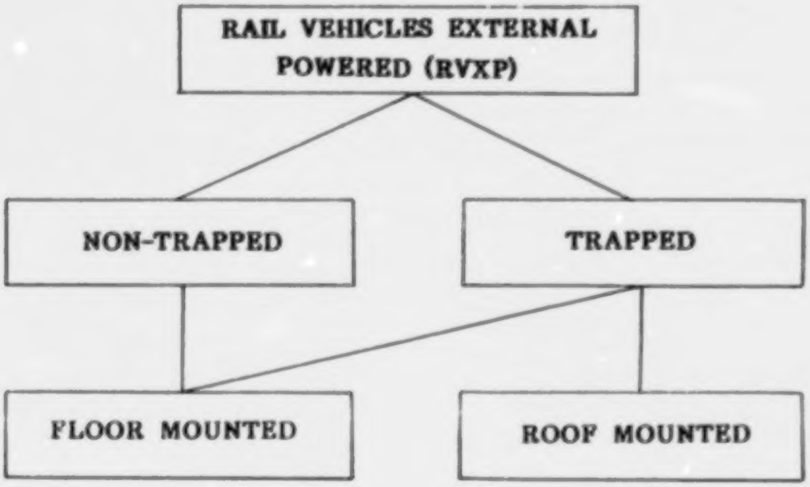

RAIL VEHICLES EXTERNAL POWERED (RVXP)
NON-TRAPPED
TRAPPED
FLOOR MOUNTED
ROOF MOUNTED

FIGURE 4-2

CLASSIFICATION OF RAIL VEHICLES EXTERNAL POWERED

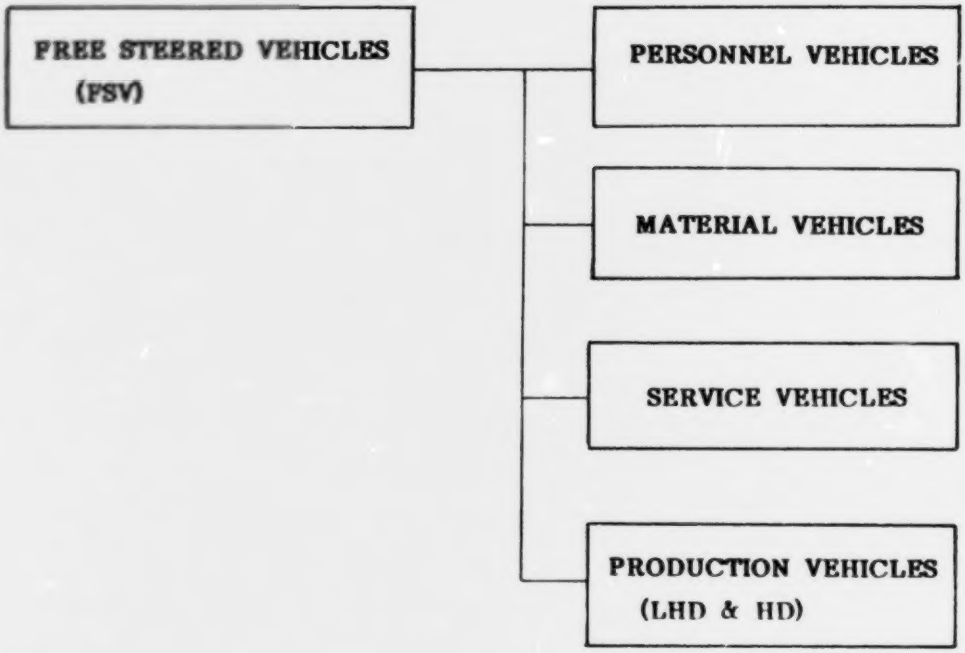

FREE STEERED VEHICLES (FSV)
PERSONNEL VEHICLES
MATERIAL VEHICLES
SERVICE VEHICLES
PRODUCTION VEHICLES (LHD & HD)

FIGURE 4-3

CLASSIFICATION OF FREE STEERED VEHICLES

SECTION 5

APPLICABILITY

5.1 INTRODUCTION

The objectives of improving transportation systems for personnel and materials are to provide improved working conditions, safety and environment; to increase reliability and average speed and to reduce costs in the overall mine operation.

Each mine is unique in the type and performance of its transportation systems and each mine typically utilizes various combinations of systems some of which may be inefficient and outdated. Efficiency can be lost as a result of a variety of factors such as the extension of the mine beyond the original plan, unexpected geological conditions, the change or modernization of production systems, regulatory restrictions, union-management agreements, the deterioration of the system over time or lack of adequate maintenance.

It has been reported that although the overall accident frequency rate in mines shows a decrease over the last few decades, there has not been a corresponding reduction in the frequency of transport related accidents.

5.2 GRADIENT CATEGORIES

To categorize the available systems we have arbitrarily selected three ranges of gradients (Figure 5-1). These are:

flat	$0 - 5^{o}$
moderate	$6^{o} - 15^{o}$
steep	$+15^{o}$

5.3 SPEED

To categorize the available systems we have arbitrarily selected three ranges of speed. These are:

slow	0 - 10 km/h
medium	11 - 30 km/h
rapid	+30 km/h

5.4 CAPACITY REQUIREMENTS

To categorize the available systems, we have arbitrarily selected three ranges of capacity. These are:

small	1 - 4 persons or up to 1 tonne
medium	5 - 20 persons or 1 to 10 tonnes
large	+20 persons or +10 tonnes

5.5 ROADWAY REQUIREMENTS

All systems are either floor or roof mounted and the requirements for roadway conditions required for efficient operation are arbitrarily categorized as fair or good.

5.6 APPLICABILITY

Typical systems for the transport of personnel and materials in underground coal mines are summarized in Table 5.1. The following general observations can be made. There are three systems that can only be used in the "flat" category. There are three systems that can be used in either "flat" or "moderate" categories. There is one system that can be used in either "moderate" or "steep" categories. Finally, there are two systems that can be used in all three categories.

In practice few mines have a geometry in which gradients fall entirely within one category. Thus the choice of system is frequently determined by the steepest gradient in the transport network. For example, inclinations in main accesses of 15° reduce the choice of equipment on grounds of gradient to eight alternatives (Table 5.1):

- non-trapped floor mounted rack locomotive (RVIP)
- trapped floor mounted rack locomotive (RVIP)
- trapped roof mounted rack locomotive (RVIP)
- non-trapped floor mounted direct rope (RVXP)
- non-trapped floor mounted endless rope (RVXP)
- trapped floor mounted endless rope (RVXP)
- trapped roof mounted endless rope (RVXP)
- ski lift

Some of these alternatives must be discounted on grounds of low capacity and inadequacy in personnel or materials carrying capacity. In practice this eliminates the trapped roof mounted endless rope (RVXP) and ski lift leaving only six options available to the system designer.

Application classifications for the "Rapid" Transport of personnel and materials in underground coal mines are summarized in Table 5.2. The optimum choice for long horizon tunnels may appear to be non-trapped or trapped rail locomotives. However since the horizon tunnels may be accessed by a decline of 15°, only systems capable of the steep duty have the capability of travelling from the surface to the far end of the horizon tunnels. In this case a locomotive system will have to have the capability of operating in a rack mode in the main access declines.

These examples serve to indicate the complexity of developing a complete transport network and of the need for networks to be designed on a site specific basis.

In the course of this study numerous examples of rapid transport systems were examined. Four systems or transportation components of particular interest for applications in existing and planned Canadian mines are the:

- endless rope haulage
- unit train with battery powered locomotive
- superbus
- rack/combination locomotive systems

Endless Rope Haulage (Data Sheet 4-32) is a well proven transportation method having been in use for most of Canada's mining history. With modern control systems, automation and handling improvements at transfers it is a very efficient means of rapid transportation of personnel and materials (Figure 5-2). Endless rope haulage can be designed for safe operation, has good gradeability (including the capability of operating to changing gradients), high reliability, speed and capacity. It is best suited to permanent installations where a high standard of track, rope roller and maintenance can be maintained.

The Unit Train (Data Sheet 4-18), operating on conventional rail with battery powered locomotives, is a logical development of conventional mining transportation methods (Figure 5-3). High speed, moderate capacity and good safety are features of unit train systems. Additional gradeability is obtainable with the application of rubber adhesion or rack and pinion drive. When used with trapped rail systems and fitted with fail-safe, heavy-duty braking, unit trains may be safely automated or operated by remote control. Combination battery and trolley wire electric power offers the possibility of long range operation. Unit trains are best suited to permanent installations where high quality track installation and maintenance can be provided, but where good roadway conditions can be maintained, can also service production or development working places.

The Superbus, (Appendix A) currently only used in surface applications (Figure 5-4), is a free steered, rubber tired, diesel powered vehicle providing a very flexible means of transportation. This concept could be adapted for underground use as part of a larger system or can in some circumstances provide a total transportation service for personnel and materials from portal to working place. The superbus consists of a tractor which tows either personnel carrying or materials handling trailers. Several trailers may be attached forming a rubber tired train. The tractor engine and gearbox combination can be specified to suit the duty and safety requirements of free steered diesel equipment underground. Conditions in large diameter, permanent tunnels such as those at the Donkin Morien Mine are similar to those encountered in highway engineering and lend themselves to the adoption of urban transit approaches to underground mines. Further development is required related to permissibility and mobility in confined spaces.

The Rack Locomotive (Data Sheet 4-24) concept of increasing locomotive performance is being developed for underground coal mines in the United Kingdom (Figure 5-5). A standard battery locomotive which operates normally on conventional track has been modified so it can engage a drive mechanism on a rack installed between the rails on steep gradient areas. This enables conventional locomotives to operate on gradients up to 18°. A further development utilizes a diesel engine and hydraulic drive.

5.7 SYSTEMS DESIGN

Personnel and materials handling systems should be considered as a complete network to transport personnel and materials from the surface to the working places and return. These networks usually comprise more than one system.

The commentary on equipment and systems provided in this report is subjective and is intended only as a guide to the designer in the considerations of improvement of existing systems, expansion plans or development of new mines. Site specific detailed analysis of each selected component or system must be conducted before finalizing the design. This analysis must consider the following:

- permanent or temporary installation in rock or in coal
- coal roof and floor
- excavation requirements and ground support
- surface and shaft system capability
- mining method, mining equipment selection and coal transportation system
- length of haul, gradients of each and horizontal and vertical curves
- number of people to be transported and location
- quantity, weight and size of materials to be handled and underground warehouse or storage requirements
- number of people required for the transport system
- number and complexity of transfers
- equipment availability, capability, performance, acceptability and regulatory certification or clearance requirements
- overall system reliability, inherent delays and reversibility
- ventilation requirements
- safety and health considerations
- the effect of emergencies or disasters on the system
- overall costs; initial, operating and maintenance
- monitoring, communications, capability of automation or remote control.

5.8 TOP SYSTEMS

The four top systems that have emerged as a result of this study are:

- Endless rope haulage (RVXP)
- Unit train (RVIP)
- Superbus (FSV)
- Rack locomotive (RVIP)

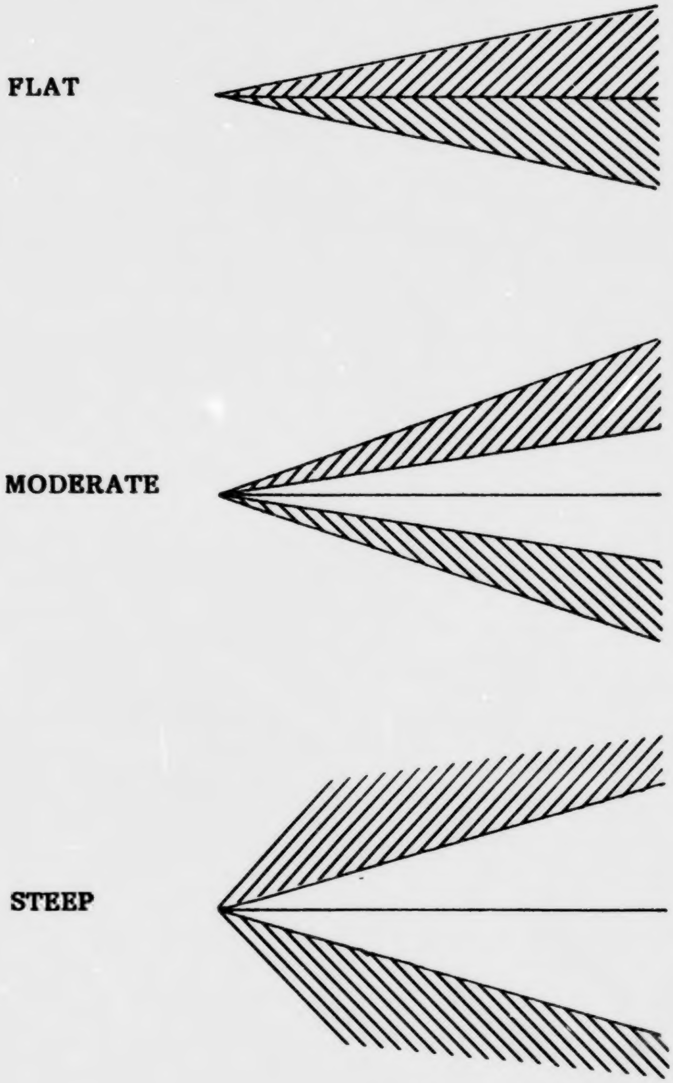
In appropriate applications these four systems can provide efficient and safe rapid transport of personnel and materials in the conditions prevailing in existing and planned Canadian mines.

TABLE 5.1
TRANSPORT OF PERSONNEL AND MATERIALS SYSTEMS CHARACTERISTICS

		Grade			Speed			Capacity			Roadway Requirements	
		Flat	Moderate	Steep	Slow	Medium	Rapid	Small	Medium	Large	Floor	Roof
RVIP - Non-Trapped Floor Mounted	Rail Locomotive	x			x	x	x	x	x	x	Good	
	Rubber tire locomotive	x	x		x			x	x	x	Good	
	Rack locomotive	x	x	x	x	x		x	x	x	Good	
	Unit train	x	x		x	x		x	x		Good	
- Trapped Floor Mounted	Rail locomotive	x			x	x		x	x	x	Good	
	Rack locomotive	x	x	x	x	x		x	x	x	Good	
- Trapped Roof Mounted	Rail Locomotive	x	x		x			x	x			Good
	Rack locomotive	x	x	x	x			x	x			Good
RVXP - Non-Trapped Floor Mounted	Endless rope	x	x	x	x	x		x	x	x	Good	
	Direct rope		x	x	x	x		x	x	x	Good	
	Main & Tail	x			x	x		x	x	x		
- Trapped Floor Mounted	Endless rope	x	x	x	x	x		x	x		Good	
- Trapped Roof Mounted	Endless rope	x	x	x	x	x		x	x			Good
FSV		x	x		x	x	x	x	x		Fair	
Conveyor Belt	Top riding	x	x		x			x	x	x	Good	Good
	Top & bottom riding	x	x		x			x	x	x	Good	Good
Ski Lift		x	x	x	x	x		x	x			Good

TABLE 5.2
RAPID TRANSPORT OF PERSONNEL AND MATERIALS APPLICATION CLASSIFICATION

			Main Access Tunnels			In-Seam Roadways			
			Horizon	Declines		Strike		Down Dip	
Available Systems			Flat	Moderate	Steep	Flat	Flat	Moderate	Steep
RVIP	Non-Trapped Floor Mounted								
		Rail locomotive	x			x	x		
		Rack locomotive	x	x	x	x	x	x	x
		Unit train	x	x		x	x	x	
	Trapped Floor Mounted								
		Rail locomotive	x			x	x		
		Rack locomotive	x	x	x	x	x	x	x
RVXP	Non-Trapped Floor Mounted								
		Endless rope	x	x	x	x	x	x	x
		Direct rope		x	x			x	x
		Main & tail	x			x	x		
	Trapped Floor Mounted								
		Endless rope	x	x	x	x	x	x	x
	Trapped Roof Mounted								
		Endless rope	x	x	x	x	x	x	x
FSV			x	x		x	x	x	


FLAT
MODERATE
STEEP

DEGREES	PERCENT	(1 IN)
5°	8.9%	11.4
5°	8.9%	11.4
15°	26.5%	3.7
6°	10.3%	9.5
6°	10.3%	9.5
15°	26.5%	3.7
15°	26.5%	3.7
15°	26.5%	3.7

FIGURE 5-1
GRADIENT PROFILES

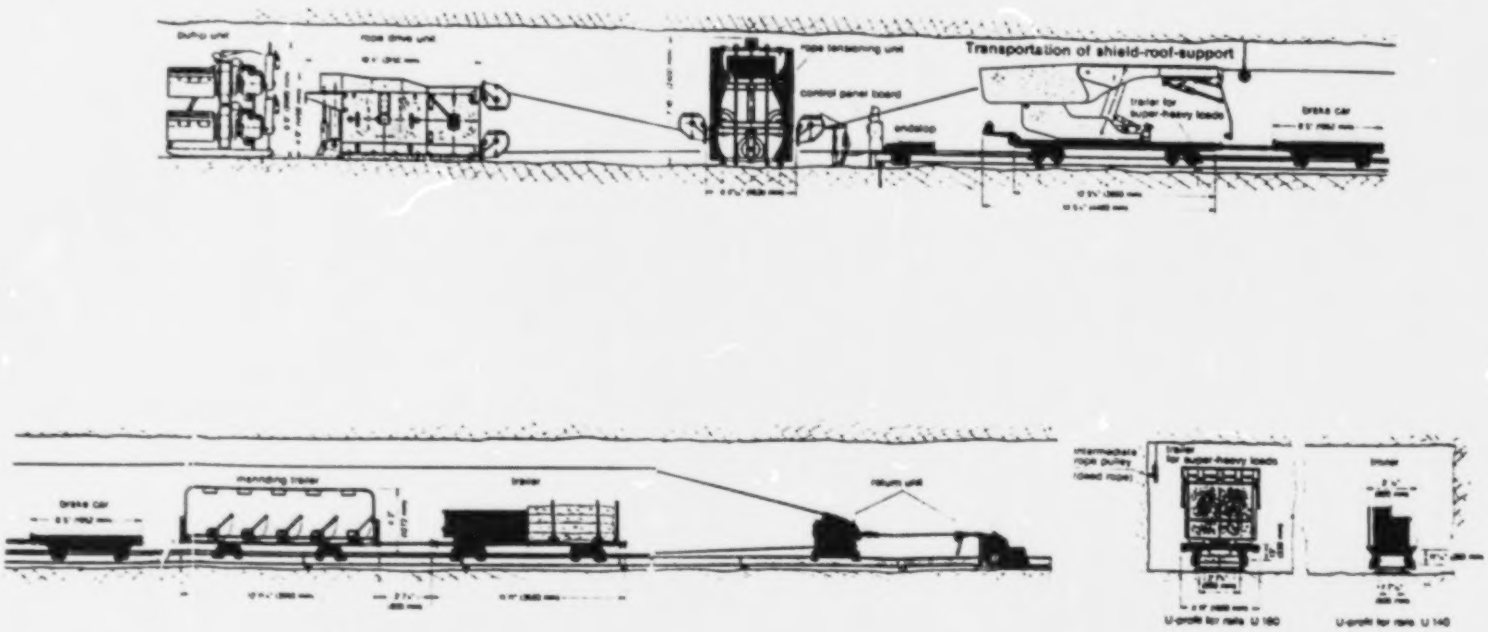

rope drive unit
rope tensioning unit
control panel board
endstop
Transportation of shield-roof-support
trailer for super-heavy loads
brake car
brake car
manriding trailer
trailer
return unit
intermediate rope pulley (dead rope)
trailer for super-heavy loads
trailer
U-profil for rails U 160
U-profil for rails U 140

FIGURE 5-2

ENDLESS ROPE SYSTEM

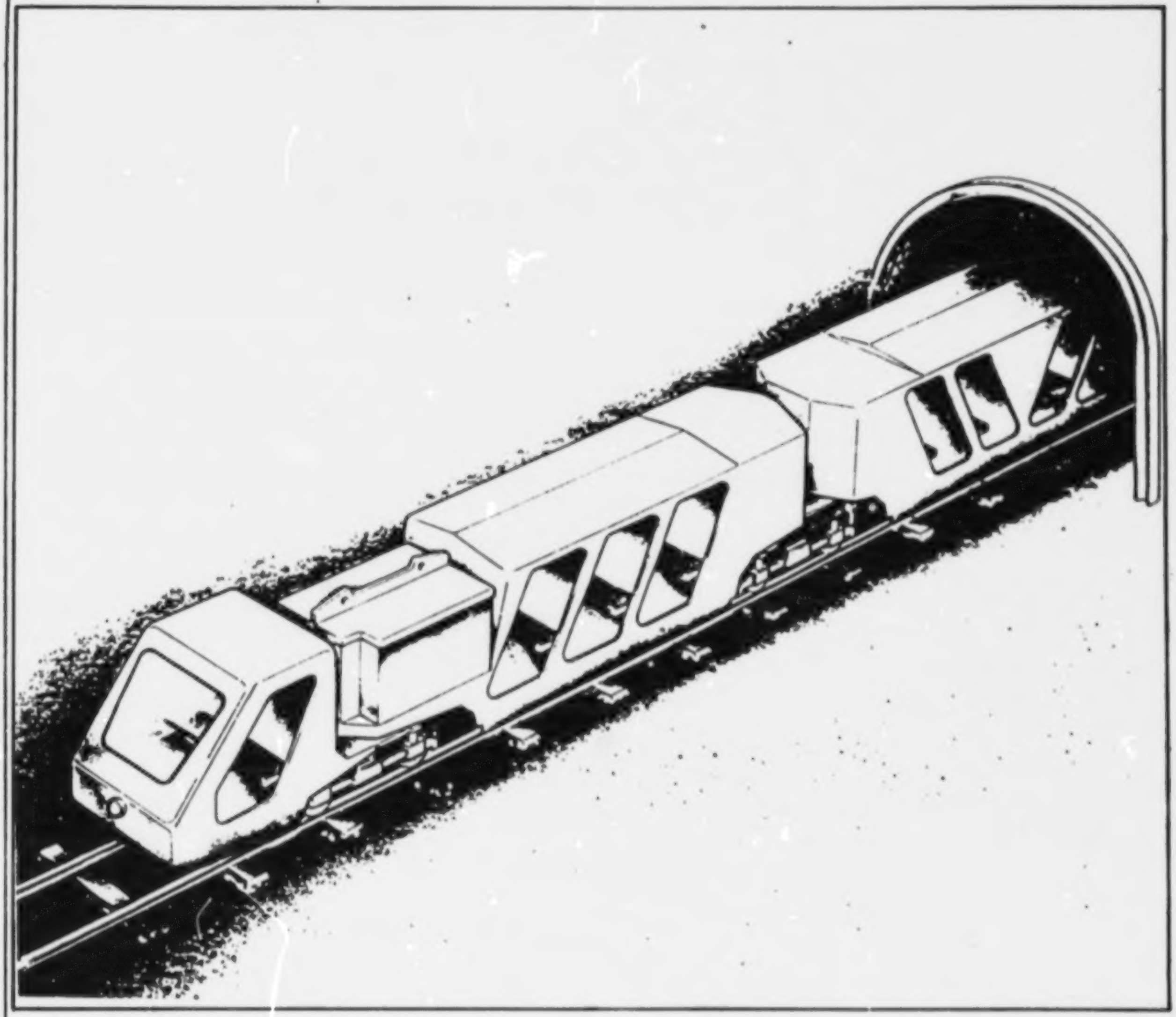


FIGURE 5-3

UNIT TRAIN

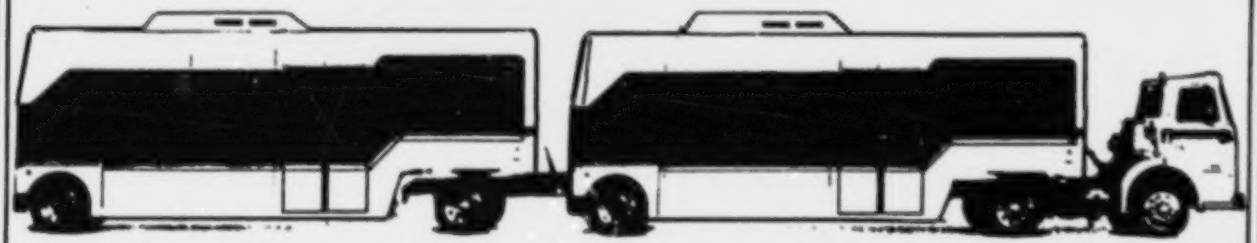


FIGURE 5-4

SUPERBUS

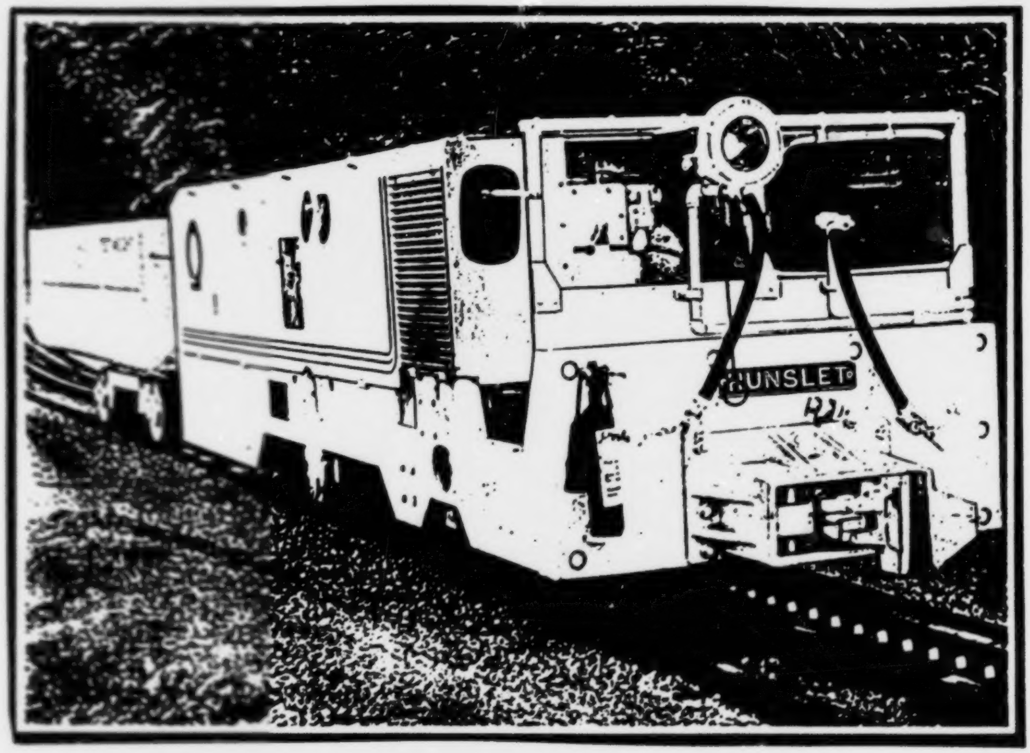


FIGURE 5-5

RACK RAIL LOCOMOTIVE

SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

To be competitive in the next decade and beyond, existing and developing Canadian underground coal mines must demonstrate high productivity, low operating costs and a high level of safety in the workplace. The transportation of men and materials in underground mines is a major and critical component of mining operations in which substantial improvement in performance can be achieved by planning and designing for efficiency, and through the utilization of innovative systems.

A wide choice of equipment types, system components and overall system designs is available to the mine transportation planner. Selection of an appropriate transportation system for a new mine is generally made before site specific operational experience can be acquired. Consequently, comparative data from other operations must be used as input to the design. Despite the wide variety of equipment available, mine designers are thus constrained by prior experience and tend to look backward at methods with demonstrated performance in other situations when preparing plans for new operations. There is considerable potential for the replacement of existing transportation systems by radically new concepts modified for underground use.

The parameters to be considered in personnel and materials transporatation system design include:

- geological and geotechnical factors
- existing installations with which new systems will interact
- excavation requirements
- overall mine design, mining method and mineral transport system

- equipment availability, reliability, maintenance requirements and operating cost
- regulatory requirements
- training requirements
- ventilation requirements
- safety and health
- control and automation potential
- emergency operation

Each mine transportation system must be designed to permit efficient interaction between its components. Transfers from one part of a system to the next can waste manpower both in terms of lost production time during personnel movements and in terms of personnel required to handle materials. Scheduling menriding to reduce waiting, containerization of supplies and use of auxilliary units such as forklifts, cranes and roller conveyors can greatly reduce the time and effort expended on transportation system transfers.

At each mine an optimum system for the movement of men and materials exists. A site specific study of the benefits and costs of a variety of systems for each application may show that the optimum system changes during the life of the mine. Projections of operating costs, particularly regarding the future cost and availability of manpower and the likely cost of fuel or power and consummables should all be taken into account when making decisions on systems which will form the lifeline of a mine for decades to come.

6.2 RECOMMENDATIONS

1. In many cases in the past the roadway configuration and mine geometry have been determined without sufficient consideration for use of optimum transportation systems. Before any new underground mine is constructed in Canada consideration should be given, at the feasibility stage, to developing the optimum personnel and materials

transport systems. If the mine design process develops the environment for an efficient rapid transportation system for men and materials then long term benefits to operating efficiency can be obtained.

2. Little quantitative data exists from Canadian or offshore mining activites related to the efficiency and economics of materials transportation systems. A systematic data collection program should be designed and implemented to enable quantitative information to be collected upon which to judge the efficiency of alternative transportation systems.

3. Mine operators should undertake quantitative analyses of their current personnel and materials transportation systems to identify those elements in the system with less than optimum efficiency. In many cases it may be possible to obtain an overall improvement in efficiency by upgrading system components. Consideration can be given to reducing the number of transfers, improving control and monitoring, adopting updated vehicle designs and other modifications.

4. Industry and CANMET should jointly sponsor further evaluation and where appropriate, development of the systems of particular interest for Canadian application:

   - Superbus concept
   - Endless rope
   - Rack locomotive
   - Unit train

   These four systems are at varying stages of development and offer opportunities for significant improvements in rapid transport of men and materials. The Superbus concept, for example, has to be evaluated for its application in underground conditions and further work is required on permissiblity and handling characteristics in confined spaces. The endless rope system requires refinement in terms of vehicle design, system control and reduction of maintenance costs. The rack locomotive system is in early stages of commercial application in mines. Applications where the rack technique is utilized for short steep sections of roadway and high speed operation can be utilized for horizon tunnels. The unit train system is now in commercial application underground on a limited scale and appears to offer considerable benefits in terms of flexibility. It is the nearest in concept to conventional surface materials and personnel handling practice as exemplified by the truck or bus. Its further application in underground coal mines will require development to improve capacity and reliability. All these issues merit the further attention of industry and CANMET.

5. Manufacturers of transportation equipment primarily designed for above ground use should evaluate their products from the perspective of underground application. Successful developments in this direction could lead to benefits to Canadian mine operators and the possibility of export earnings through the supply of such equipment to the mining industries outside Canada.

6. CANMET should keep under review the rapidly emerging technology being developed for men and materials system control, communications, monitoring, central dispatch, transponders and micro-processor applications.

7. This study specifically addressed only personnel and materials transportation in underground coal mines. However, the transportation system must be capable of handling great quantities of heavy equipment where mechanized longwall continuous mining is used, as well as interfacing with the mineral production haulage equipment.

Shield supports are widely used in almost all major coal producing centers including Canada and face to face moves are major undertakings as shield weights range up to 20 tonnes. As well, there is the shearer, powered loader, armoured face conveyor, stage loader and other secondary equipment to be transported.

Monorail systems have special elaborate auxiliary equipment suitable for the transport of longwall equipment. Transferring these heavy loads from floor mounted railroad systems requires special arrangements and installations such as powered chainblocks or special forklifts. For example, a skid plate with an integral turntable has been developed at Hem Heath Colliery for transporting supports of about 10 tons each along a longwall face. The support is transferred from the railroad car to the skid plate using powered chainblocks and is pulled into the face area with a hydraulic winch. The plate is then rotated 90° and the support is slid into its appropriate position using hydraulic rams and hand operated hoists.

A number of FSV's are available, such as Eimco's Quick Detachable Systems (QDS), which have the flexibility of quickly changing from production buckets to flat bed containers or fork lift containers suitable for handling heavy equipment. In addition, other QDS containers are utilized for manriding, materials, stone dusting, shotcreting, first aid, fire fighting and servicing. Noyes has available a highly maneouverable FSV designed to fit around, lift and transport roof supports or other equipment up to 27 tonnes. Other manufacturers such as Ingersoll Rand build flat bed trailer vehicles and use winches to pull the roof supports onto the trailer.

For face conveyors or stage loaders, Eimco has developed a special hydraulic transfer system to facilitate moves at face ends and development heading. The U.S. Department of Energy has completed a study by Ketron, Inc. addressing the problem of handling materials from the end of the transport system to the working face. They have also prepared a handbook for use by mine operators. This study should be reviewed to evaluate its usefulness in developing efficient means of dismantling and transporting longwall equipment in Canadian underground coal mines.

8. This report is a summary of a large volume of current systems and equipment for the rapid transport of personnel and equipment in underground coal mines and illustrates the necessity for a greater emphasis on transport by management. Therefore operators may be well advised to assign one of their engineers to this duty on a full time basis.

APPENDIX A

URBAN TRANSIT AND HEAVY INDUSTRIAL SYSTEMS

A-1 Evaluation of Rapid Transport Systems from Other Fields
  1.0 GENERAL
  2.0 TRANSPORTATION REQUIREMENTS
    2.1 Transport of Personnel
    2.2 Transport of Materials and Equipment
    2.3 Cross-section
    2.4 Flexibility
    2.5 Reliability/Maintainability
    2.6 Gradeability
    2.7 Availability
    2.8 Power
    2.9 Automatic Operation
    2.10 Switching
    2.11 Cost
  3.0 CANDIDATE SYSTEMS
    3.1 General
    3.2 Systems
A-2 Candidate Systems Descriptions
A-3 Bibliography

APPENDIX A-1

URBAN TRANSIT AND HEAVY INDUSTRIAL SYSTEMS

EVALUATION OF RAPID TRANSPORT SYSTEMS FROM OTHER FIELDS

1.0 GENERAL

The purpose of this working paper is to evaluate rapid transport systems from other fields and to identify a number of candidate systems which may have application in underground coal mines.

2.0 TRANSPORTATION REQUIREMENTS

The application of a rapid transport system to an underground coal mine imposes a number of requirements on the system. These requirements include:

2.1 Transport of Personnel

The main purpose of the proposed rapid transport system will be to move personnel from the surface to the work face reasonably quickly and with a high degree of safety.

The value of time for personnel travelling on the system will be high. Travel time can be reduced in a number of ways:

- Increased speed
- Reduced waiting time
- Direct travel

These factors must be balanced against the capital and operating costs which may be incurred by adopting high speeds, frequent service and direct travel.

For example:

If travel distance is 10 km, travel time will be 15 minutes at 40 km/h and 10 minutes at 60 km/h. The 5 minute saving may not be justified by increased capital cost of the faster system. It may be more cost efficient to reduce the average waiting time for transportation by increasing the number of vehicles available.

Similarly the travel time will be affected by the need to transfer from mode to mode. However, it may not be practical to construct a system that will operate at relatively high speed and also negotiate severe grades. These will therefore be trade-offs between capital expenditures to reduce or eliminate the need to change mode and the time loss in making the transfer.

There is also a requirement to transport those personnel changing shift within a relatively short period of time. Some staggering of times for shift change are possible but it would be desirable to move miners on and off shift within a one hour period. For 500 underground workers coming on shift, a 50 passenger vehicle at 5 minute headway will provide capacity for 600 passengers. If the round trip time out to the face and back is 30 minutes, then 6 vehicles can provide a 5 minute headway.

Safety will be a prime requisite for a system transporting personnel. There are well developed control systems in the transport industry which can insure that vehicles are separated by safe stopping distances and that vehicles do not enter a track section with vehicles moving in the opposite direction.

An enclosed vehicle, with all passengers seated, would give added safety.

2.2 Transport of Materials and Equipment

With a rapid transport system in place for carrying personnel, the system would be available for the transport of materials and equipment between shift changes. Either different vehicles operating over the guideway or some method of changing the vehicle configuration would be required.

The cargo would have to be of dimensions that would fit inside the vehicle or the tunnel clearance lines.

2.3 Cross Section

In an underground application the construction costs is sensitive to the system cross sections. As the cross section increases, the amount of material to be excavated and the span to be supported, increases. The system cross section will be affected by a number of factors:

- Width and height of vehicle
- Dimensions of track structure
- Dimensions and location of power supply
- Space for ancillary equipment
- Tolerance required for steering
- Need for walkways in tunnel

The vehicle dimensions will be dictated by the number of personnel and the dimensions of materials and equipment to be carried.

Some systems, for example, magnetic levitation, have significant track and guidance structures to be incorporated into the tunnel. Similarly other systems, such as the steel wheel, steel rail systems with electric traction must provide space for trolley wire. Space must be provided for ancillary equipment such as signals and traction power equipment. In many cases, the tunnel will carry equipment, ducts and piping for mine operations. It may also serve as a ventilation duct.

The method of steering has an impact on tunnel dimensions. Where manual steering is used the tunnel width is increased to provide for the steering acuity of the driver. Depending on speed, sufficient clearance must be provided to allow the driver to react to the vehicle wandering off line and correct the direction. The proximity of the tunnel walls and the amount of lighting provided also has an impact on the drivers ability to follow the roadway.

Tracked and guided vehicles, on the other hand, follow a relatively tight path. Allowances must be made for the chording of the vehicle on a curve, sway of the suspension and the effect of a broken spring or flat tire; otherwise close tolerances are possible. Tunnel width can also be increased by the need for a walkway for personnel walking through the tunnel. In some cases, safety pockets are provided for personnel to enter while a vehicle is passing.

Transport systems can be arranged with single tunnels through most of the length and two way tunnels at intervals for passing vehicles. While this can result in delays while vehicles are passing, capital costs are substantially reduced. A positive signal system is required to prevent vehicles moving in opposing directions from entering the single tunnels.

2.4 Flexibility

The system selected should have the flexibility to be extended as mining operations move to new seams. It should also have the flexibility to adapt to changing conditions or to improved technology.

2.5 Reliability/Maintainability

The system selected should have a high degree of reliability; the system should be easy and economic to maintain by personnel with the skills to be found in a mining operation. Spare parts should be available from one or more suppliers throughout the expected life of the facility.

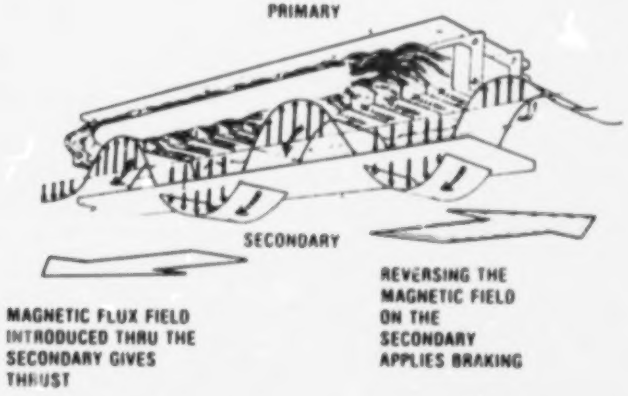
The underground environment is severe and the system selected should be rugged, simple and resistant to corrosion.

2.6 Gradeability

The system selected may be required to have the ability to operate on grades up to 15°. This is an extreme requirement not usually made on transit systems.

Most steel rail systems are designed for a maximum 3° grade although there are examples of short sections on 6° grade. Rubber tire systems operate on grades up to 15° where snow and ice are not a factor, (San Francisco). In these cases, performance on the severe grade is low and speed on the rest of the route is reduced by the need for a high axle ratio. (Motor r.p.m./wheel r.p.m.).

The linear induction motor is a magnetically induced link between the vehicle and wayside. As such, it does not depend on adhesion between wheels and track or roadway. In theory, high grades can be climbed or descended by the linear motor; in practice this is not done because it is uncomfortable for standing passengers. Severe grades also require a motor of high capacity; if the motor is located on board the car it must be sized for the severe grade and its capacity cannot be used economically on the rest of the route. In some linear induction systems, the motor primary is at way side. In these cases, high capacity primary coils can be installed on the severe grade and regular capacity coils on the rest of the route. The general principle of the Linear Induction motor is shown below:


PRIMARY
SECONDARY
MAGNETIC FLUX FIELD INTRODUCED THRU THE SECONDARY GIVES THRUST
REVERSING THE MAGNETIC FIELD ON THE SECONDARY APPLIES BRAKING

LINEAR PROPULSION MOTOR

It may be desirable to examine the economics of flattening grades in order to get improved performance of the system, both on the grade and throughout the route. It is also possible to provide hybrid systems using either a cog drive or a chain drag, up and down the severe grades.

2.7 Availability

The availability of systems should be examined. It is unlikely that a large number of vehicles will be required and custom designed and built vehicles may be costly due to high set-up costs. Standard units such as urban buses or units in production for another project may be more economical. The availability of spare parts in the future should be examined.

2.8 Power

A number of power systems are available:

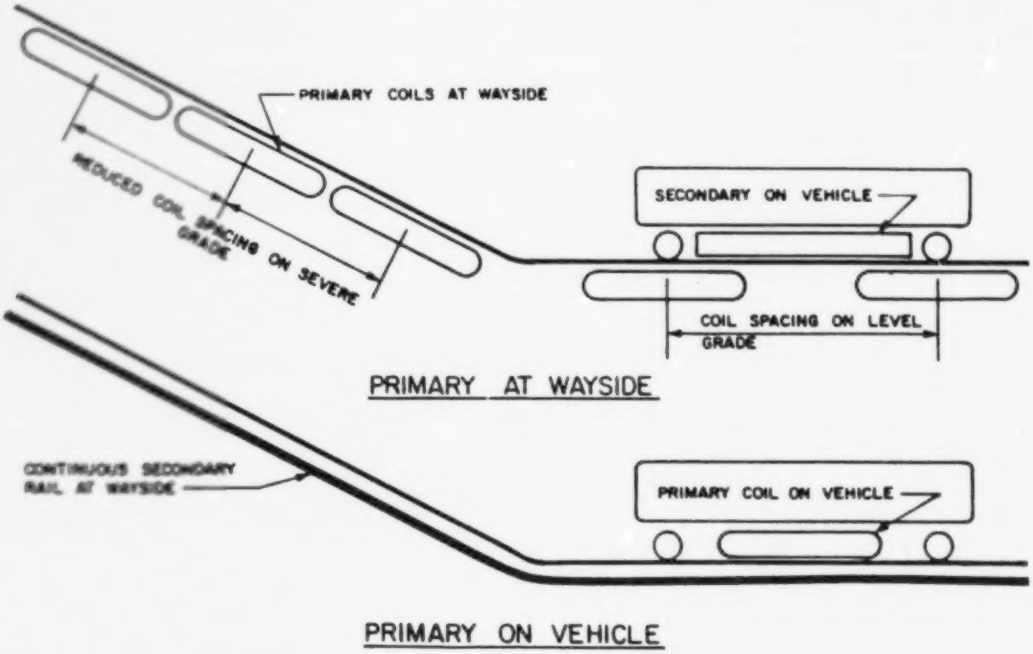
- Diesel
- Rotary Electric Motors
- Linear Induction Motors
- Mechanical Drives

The number of vehicles required to provide the necessary transport will be limited. Mine ventilation may be able to handle the exhaust fumes from internal combustion engines. This would free the rapid transport system from the need to follow power supplies. The diesel engine is rugged and maintenance skills easily obtained.

Rotary electric motors require power supplies to the vehicle and the vehicle must generally follow the power lines. Hybrid and battery power supplies could be considered allowing limited operation away from power supplies.

The linear induction motor is a relatively new development in the urban transit field. The motor is rugged and simple with no moving parts. Some linear induction motors, with the primary coils at wayside, have been applied in mines. The principle of the linear motor is shown in Figure 1.

Figure 1 - Linear Motor


PRIMARY COILS AT WAYSIDE
REDUCED COIL SPACING ON SEVERE GRADE
SECONDARY ON VEHICLE
COIL SPACING ON LEVEL GRADE
PRIMARY AT WAYSIDE
CONTINUOUS SECONDARY RAIL AT WAYSIDE
PRIMARY COIL ON VEHICLE
PRIMARY ON VEHICLE

Mechanical drives, such as rope drives, have had limited although long-standing application in transit. Examples of mechanical drive systems are the San Francisco cable car and a proposed cable haul installation at Sun City in Bophuthatswana in Southern Africa being installed by Otis Technologies.

2.9 Automatic Operation

Automatic operation would reduce the labour input to the system and would eliminate the human element in the safety of operations. Automatic operation would allow empty vehicles to be routed to destination without the need for a driver on board. It can also control separation of vehicles for safety. However, automated operation introduces complexity and special skills are required for maintenance.

2.10 Switching

Some rapid transport systems have complex, large and slow moving switches. This requirement can make terminal operations and vehicle passing difficult and costly.

2.11 Cost

All the foregoing factors have a bearing on the life cost of the rapid transport system. A series of trade offs are required in order to select the optimun system for each application. These include:

- Capital cost vs operating cost;
- Guided systems vs manual steering;
- Impact of severe grades on overall operations;
- Future availability of system components and spare parts;
- Reliability of system;
- Flexibility to operate on the surface as well as underground;
- Flexibility for future relocation and/or expansion of the system.

3.0 CANDIDATE SYSTEMS

3.1 General

From the broad range of systems providing rapid transportation in public transit and other fields, those systems which might possibly have application for rapid transport in underground mines have been identified.

Clearly, a number of the urban systems do not meet the requirements for mines and should not be investigated further. The preliminary list has therefore been reduced to a short list of candidate systems which can be considered for application. These candidates are described in Table 1, "Description of Candidate Systems". System specifications are contained in the Appendix.
Table 1 lists several generic systems with examples of each that are currently in operation or being commissioned.

Dimensions of the vehicles for each system are given but it would be possible to select similar systems with other dimensions. The cross-sectional area is based on a rectangular tunnel for a single track or laneway; standard clearances have been provided. This area will decrease if an arched tunnel is used.

The seated capacity is based on the examples given. This capacity would vary depending upon the configuration selected.

Maximum speed can vary depending upon the motor and gear ratio selected. Where high gradeability is required, maximum speed may be sacrificed.

Availability is based on the current situation. At a point in time closer to the actual implementation the situation may have changed. A special order may entail additional costs for tooling-up for a small production run. Ideally a

TABLE 1
RAPID TRANSPORT OF PERSONNEL AND MATERIALS URBAN TRANSIT AND HEAVY INDUSTRIAL CANDIDATE SYSTEMS

System	Examples	Height	Width cm.	Length	Seated Capacity	Max. Speed km/H	Max. Grade degrees	Availability	Reliability Maintainability	Steering Method
Steel Wheel on Steel Rail with Rotary Electric Motor	CLRV (Toronto Streetcar)	4.5	2.6	13.4	64	80	6	In Production 1985	Good	Track
Steel Wheel on Steel Rail with Linear Induction Motor	Scarborough Rapid Transit & Vancouver ALRT	3.6	2.5	12.7	40	80	3	In Production 1985	Limited Experience	Track
	Wedway People Mover Houston Airport	2.5	1.6	4.2	12	25	3	Special Order	Good	Track
Rubber Tire Diesel Engine	Superous	3.5	2.6	19.8	58	90	15	Demonstration Only	Good for Tractor Limited Experience for Trailer	Manual Steering
	Orion II	2.5	2.45	9.6	26	80	15	In Production 1985	Limited Experience	Manual Steering
Rubber Tire Rotary Electric Motor	Trolley Bus Toronto and Vancouver	4.0	2.6	12.6	33	60	15	Not In Production 1985	Good	Manual Steering
Rubber Tire Rotary Electric Motor	Westinghouse People Mover Miami & Tampa Airports	3.4	2.85	11.2	92 Standing	50	5	Special Order	Good	Guided
Magnetic Levitation with Linear Induction Motor	M-Bahn West Berlin, Germany	3.2	2.3	11.8	24	80	15	Special Order	Limited Experience	Guided
Air Bearing with Cable Haul or Linear Induction Motor	Otis Hovair Duke University Durham, N.C.	2.9	2.25	4.6	29 Standing	30	15	Special Order	Good	Guided

small order would be added to a larger order for a reasonable number of vehicles to be processed.

Reliability and maintainability is, in many cases, dependent upon the maintenance skill of the individual operators. In some examples, the system has not been in operation for a sufficient period of time to allow a judgement on reliability and maintainability to be made.

3.2 Systems

The following information will supplement Table 1.

Steel Wheel on Steel Rail
Rotary Electric Motor

The Canadian Light Rail Vehicle (CLRV) as produced by the Urban Transportation Development Corporation (UTDC) is an example of this system. It is currently operating in Toronto, and additional units are being produced to replace the existing PCC streetcars which date from 1946.

The CLRV is a four axle vehicle; six axle articulated vehicles are operating in Calgary and Edmonton with higher passenger carrying ability. The CLRV is a single end configuration requiring a turning loop at each terminal, however, it can be constructed with a driving position at either end. This would be desireable since the construction of an underground loop would be costly.

Since the CLRV depends upon adhesion betweeen the steel wheel and the steel rail, the gradeability of the vehicle is limited. In order to function on a 15° grade some positive traction and braking method would be required such as a rack and pinion on grades exceeding about 6°.

Guidance is provided by a flanged wheel riding on the track. This is a positive system which limits the tunnel width required. The track switch is well proven and simple. Traction power is at 600 volts d.c. distributed to the car on an overhead trolley wire.

The CLRV requires a man on-board to operate the vehicle. The ability to carry cargo would be limited without extensive modification.

Steel Wheel on Steel Rail Linear Induction Motor

Examples of this generic type of transport system are the Scarborough Rapid Transit and Vancouver ALRT systems; and the Wedway system operating at Houston Internation Airport and at Disney World. The ALRT system has undergone extensive testing and demonstration but has not yet entered revenue service. The Scarborough system is scheduled for completion in April 1985. The Wedway system has been operating at Disney World since 1975 and at Houston Airport since 1981.

In the ALRT system the primary coil of the linear induction motor is located on board the vehicle. The secondary of the motor is a steel reaction rail mounted between the tracks. Power is picked up by the car from supply rails. The Wedway system is based on primary motor coils located at wayside with the secondary on the vehicle. Detectors at wayside energise the primary coils as the vehicle passes. The Wedway system has the advantage that the heaviest part of the motor and the motor control is at wayside with ony the inert reaction part of the motor on board. There is no requirement for the vehicle to pick up traction power. However, a low capacity power source is required for lighting, heating and other electrical requirements on board the car. As a result of removing the traction power primary, control system and heavy duty power pickup, the vehicle becomes relatively simple and weight is low. On the other hand, a large number of secondary coils are required and this can be costly.

The linear induction motor provides a magnetic link between wayside and the vehicle and does not depend on adhesion between the steel wheel and steel rail. In theory, high grades can be negotiated but some form of mechanical back up brake is required in case of loss of power.

Rubber Tire - Manual Steering
Diesel Engine

This system is based on the bus and truck vehicles widely used in all forms of transport. In addition to the standard vehicles, two recently developed buses suggest themselves as candidates that could be considered.

The Superbus is a tractor trailer combination utilizing a standard tractor unit pulling one or two trailers. Trailers can be equipped for either passenger or material handling. The appropriate number and type of trailers can be coupled to the tractor depending on the transport needs. The tractor can be geared and powered to handle the grades and speed requirements of the application. This system gives a high degree of flexibility.

The Orion II bus is manufactured by Ontario Bus Industries. This is a small but robust bus of stainless steel construction. Front wheel drive allows a low flat floor and a low bus profile. This may be an attraction in minimizing underground construction. Special axle ratios can be provided for use on severe grades.

Rubber Tire - Manual Steering
Rotary Electric Motor

An example of this system is the trolley bus as operating in Toronto, Vancouver and Edmonton. Powered with a rotary electric motor the trolley bus gives high performance with low maintenance. Low maintenance on the vehicle is offset by the need to install and maintain power distribution wires.

The trolley bus has excellent gradeability. The attached illustration shows a trolley coach operation on a 15° grade on Union Street in San Francisco.

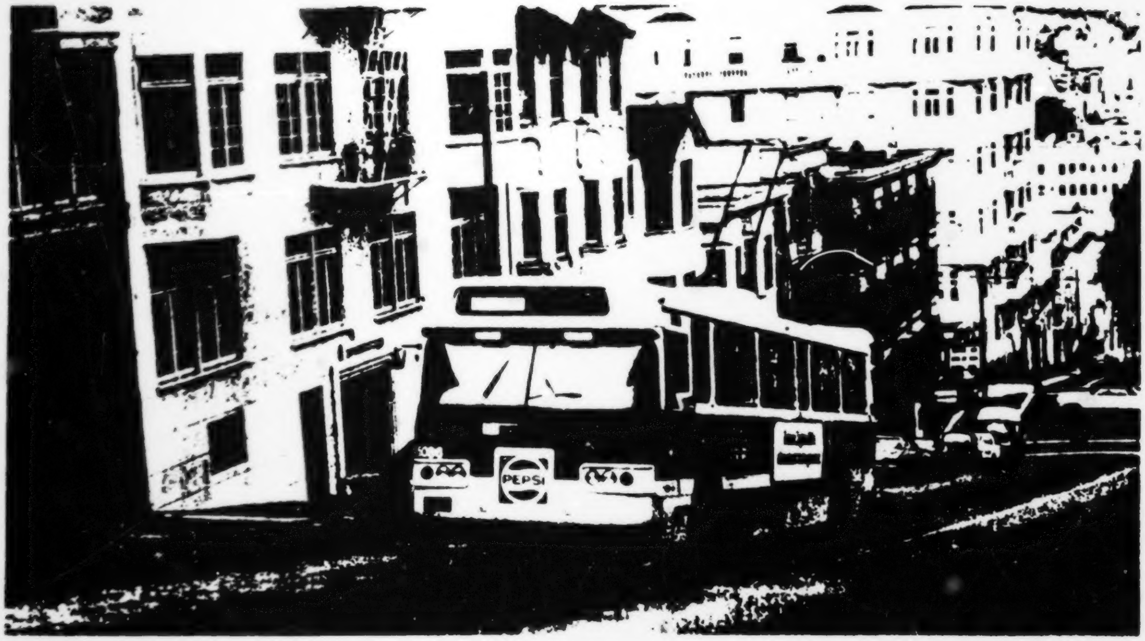


Figure 2 - Trolley Bus on 13° grade

As options, trolley buses can be equipped with either batteries or an auxiliary internal combustion engine which will permit the bus to operate off the power conductors, although at reduced performance.

Trolley buses are manufactured in Canada by Flyer Industries. No trolley buses were in production at the beginning of 1985. An order for a small number of trolley coaches may result in a high unit cost unless a larger order is already in production.

Because of overhead power distribution wires and lane width required for manual steering, tunnel dimensions are relatively large.

Rubber Tire - Guided
Rotary Electric Motor

The most successful example of this type of system is the Westinghouse People Mover system as installed at Miami and Tampa Airports. In these cases the vehicles operate as shuttles from the main terminal to sattelite terminals.

Because of the relatively short distance, most passengers stand with only a few seats provided. A configuration with high density seating is possible.

The provision of guidance and the use of a power distribution rail at track level reduces the cross section of the tunnel, compared to manually steered systems. Power distribution at track level may raise safety problems. Operation is automatic with no operator on-board.

Magnetic Levitation
Linear Induction Motor

The M-Bahn is a German development which has been demonstrated in Brunswick since 1976 and a 1.6 km operating line is now under construction in West Berlin. This system uses permanent magnets to provide levitation. Other systems utilize electromagnets but the use of permanent magnets eliminates the operating cost of energy for magnetic levitation.

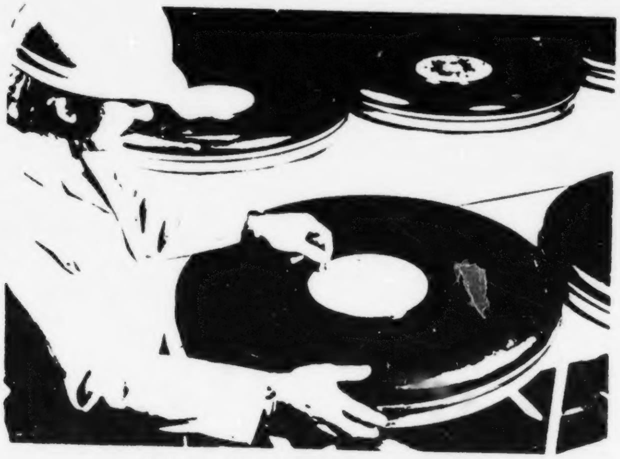
Guidance is provided in the M-Bahn system by guide wheels. The proper air gap between the primary coils on the guideway and secondary platen on the vehicle is maintained by rollers. Braking is achieved by reversal of the motors or by mechanical brake pads acting on the guide rails.

The primary or powered coils of the linear induction motor are located on the track structure. The secondary armatures are the permanent levitation magnets. This concept gives a light weight vehicle with no motor control on-board. The wayside primary coils can be designed to give additional thrust where required. For example, on severe grades more powerful coils can be installed to provide the thrust required to overcome gravity. Similarly these heavier primary coils can provide the braking forces to control the vehicle on its descent.

Air Bearing
Linear Induction Motor

The best known example of this system is the Otis Hovair currently operating at Duke University in Durham N.C. The UTDC Transporter is a somewhat similar system with a test installation at their research centre in Kingston, Ontario.

The Hovair uses air suspension pads on the bottom of the vehicle chassis. These pads provide no directional restraint and it is possible to move the car laterally as well as longitudinally.



AIR SUSPENSION PADS ON BOTTOM OF CHASSIS

Figure 3 Air Suspension Pads

The Otis concept includes moving the vehicle laterally onto an elevator for a change in grade.

In the Transporter case, the air bearings are in grooves which guide the vehicle along a fixed path.

APPENDIX A-2
CANDIDATE SYSTEMS DESCRIPTIONS

- CLRV - Urban Transportation Development Corporation
- LRV - Siemens - Duwag
- ALRT - Urban Transportation Development Corporation
- Wedway - Bombardier
- Superbus - Superbus Inc
- Orion II - Ontario Bus Industries
- Trolley Bus - Flyer Industries
- People Mover - Westinghouse
- M-Bahn - Magnetic Transit Inc
- Hovair - Otis Technology
- Transporter - Urban Transportation Development Corporation

CLRV

General Description of Vehicle:

A single-ended, 4-axle vehicle capable of operating singly or in trains of as many as 6 units. Propulsion by two, 180-hp motors, each driving two axles (360 hp per car). Solid state chopper control with blended, regenerative braking.

General Description of Truck (Bogie)

UTDC fabricated bogie. Rubber and steel primary suspension (coil springs) and airbag secondary suspension with load weighing. Suspended motor for low unsprung mass.

Vehicle Performance:

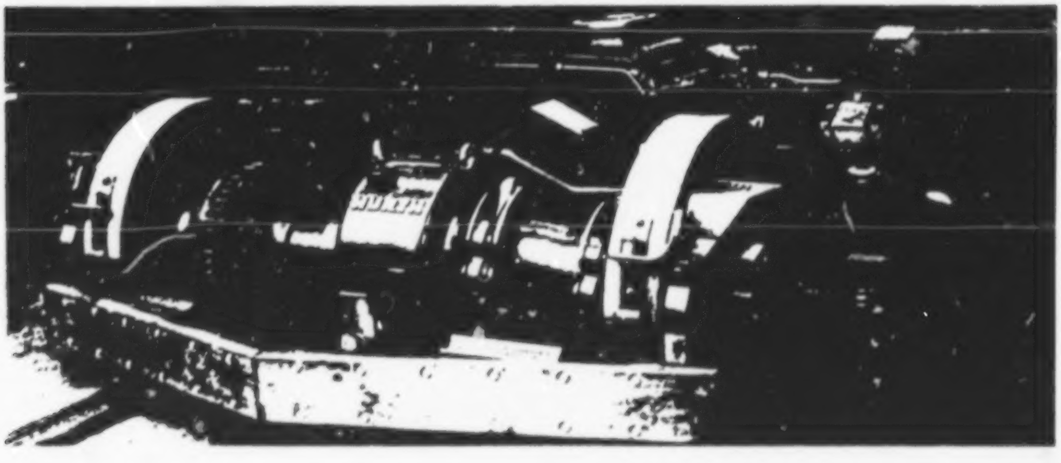
Maximum Velocity	50 mph	(80.5 km/h)
Maximum Grade	±8%	
Service Acceleration (Initial)	4.84 ft./s^2	(1.48 m/s^2)
Service Deceleration ..	5.13 ft./s^2	(1.57 m/s^2)
Emergency Deceleration (Average from 50 km/h)	9.53 ft./s^2	(2.92 m/s^2)
Jerk—Normal (depending on status of roll back prevention circuit when measured ..	3.67-5.1 ft./s^3	(1.12-1.56 m/s^3)
Maximum	5.86 ft./s^3	(1.52 m/s^3)
Minimum Horizontal Curve Radius	36 ft.	(11 m)
Single and Coupled Vehicles		
Minimum Vertical Curve Radius	400 ft.	(122 m)
Capacity (typical seating arrangement)	46 seats, 85 standees	
Area per Standee (crush loaded)	1.5 ft.^{2}	(0.14 m^2)

Dimensions:

Length	50.67 ft.	(15,444 mm)
Width	8.5 ft.	(2,591 mm)
Height, Rail over Roof ..	11.04 ft.	(3,365 mm)
Height, Rail to Floor	3.02 ft.	(920 mm)
Empty Weight	51,000 lbs.	(23,135 kg)
Gross Weight	70,800 lbs.	(32,120 kg)
Inside Width	7.68 ft.	(2,340 mm)
Headroom, Centre Aisle ..	6.68 ft.	(2,035 mm)
Width, Centre Aisle ...	23.78 ins.	(604 mm)
Doorway Width	59.6 ins.	(1,514 mm)
Doorway Height	85.43 ins.	(2,170 mm)
Step Height (first)	10.0 ins.	(255 mm)

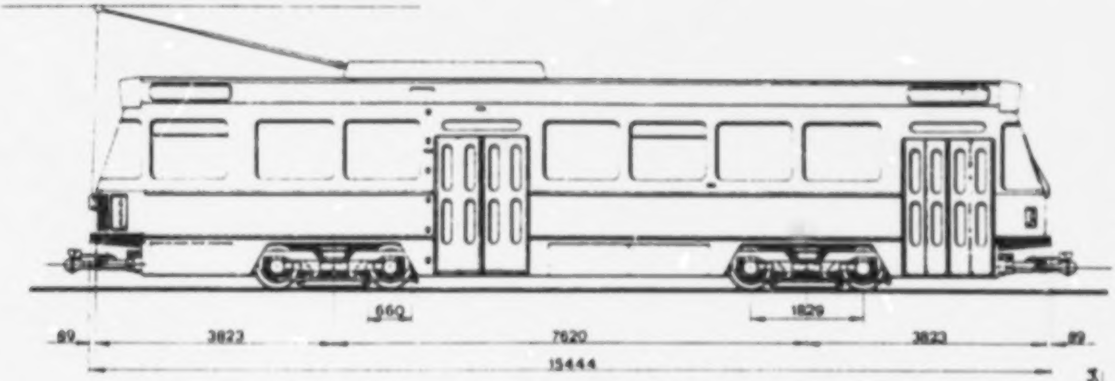
Suspension, Propulsion and Braking:

Trucks (Bogies)	2, each equipped with 1 motor powering 2 axles
Truck Centres	25 ft. (7,620 mm)
Wheel Base	6 ft. (1,829 mm)
Wheel Diameter (New)	26 ins. (660 mm)
Track Gauge	4.71 to 4.91 ft. (1,435 to 1,495 mm)
Motors, Number & Type	2 d.c. motors, 1 per truck
Rating per Motor	134 KW
Gear Ratio	5:56:1
Type Drive ..	Angle drive with Cardan Coupling
Service Brakes	Regenerative/dynamic electrical braking modes and axle-mounted disc brakes
Emergency Brakes	Electro-magnetic track brakes plus spring applied disc brakes

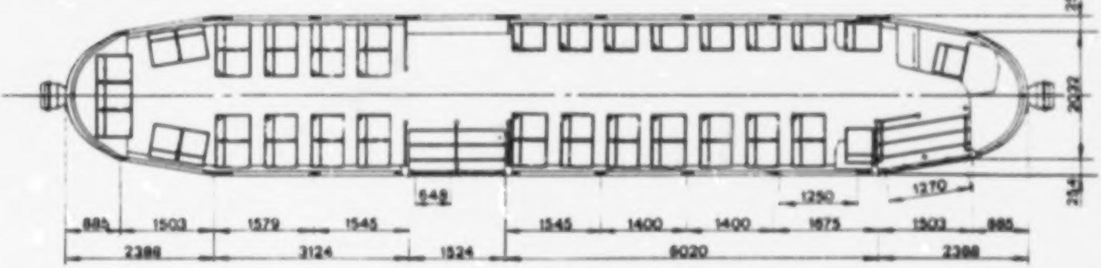


The CLRV fabricated, mono-motor truck was designed for ease of maintenance and features a 4-point airbag secondary suspension system and resilient steel wheels to provide a quiet, comfortable ride.

CLRV (cont'd)



Canadian Light Rail Vehicle (CLRV)



CLRV seating arrangements can be modified according to the operator's specific requirements.

Electrical and Control Systems:

Line Voltage	600 VDC + 120V - 300V
Power Collection	Overhead, Trolley or pantograph
Exterior Lights	1 headlight
Interior Lights	Inverter Ballast 36 VDC
Destination Signs	Electrically driven
Propulsion Control	Semi-automatic acceleration and deceleration chopper type with anti-spin and anti-slide control
Instruments & Controls	Speedometer, control switches and lights, passenger stop request, foot operated brake, accelerator and dead-man control

Body:

Frame	Low alloy, high tensile (LAHT) steel
Exterior Walls	LAHT steel
Interior Finish	Royalite trim panels
Insulation	Fibreglass and K 13 .
Floor	Corrugated steel with plywood overlay
Steps	Removable stainless steel
Doors	Two, bi-fold on right hand side
Windows	Combination fixed and

Heating	Electric; forced air
Ventilation	Overhead fresh air
Air Conditioning	Optional
Seats	Stainless steel, cantilevered

Variations and Options:

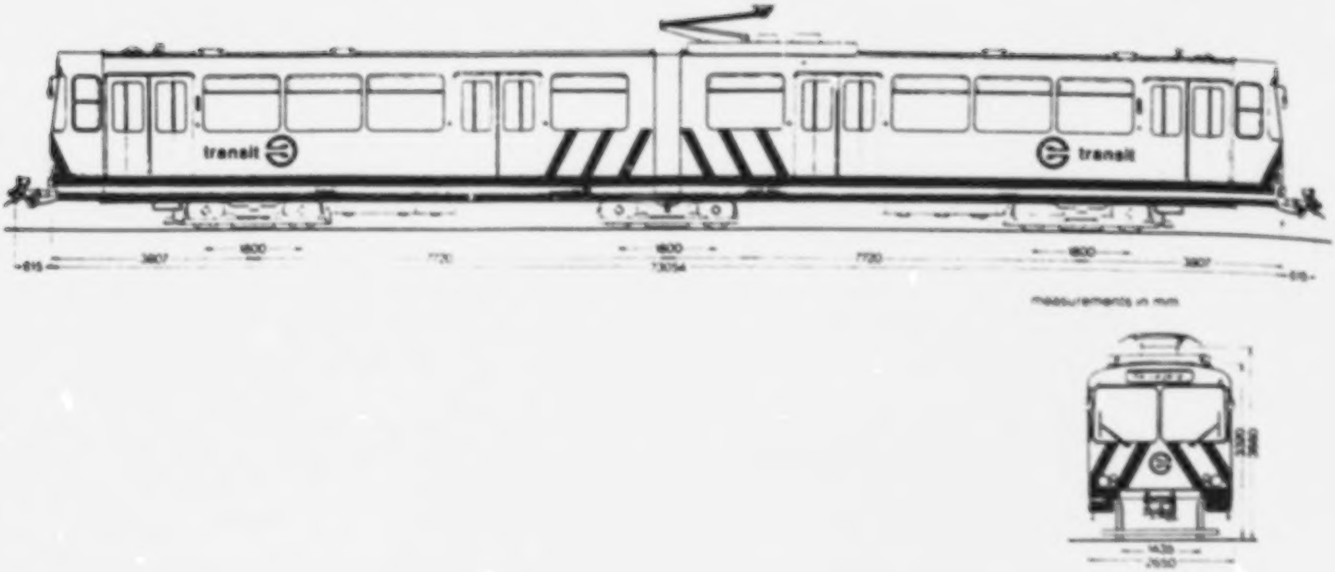
The modular design of the Canadian Light Rail Vehicle permits variations in length up to 66.0' (20000 mm) according to operator requirements. In addition, optional seating equipment and interior arrangements are available. Maximum velocity can be increased to 70 mph for LRT applications.

Design and Development

The CLRV was designed and developed in cooperation with the Toronto Transit Commission to ensure that the vehicle incorporated maintenance, reliability, passenger and driver comfort features based on the extensive experience of a major operator of light rail vehicles. The TTC purchased a total of 196 units.

The CLRV was designed to permit convenient, and low cost maintenance. Batteries, brushes, chopper control equipment and wiring are easily accessible. Special diagnostic equipment is available for trouble-shooting the propulsion system and adjusting performance settings in the main-

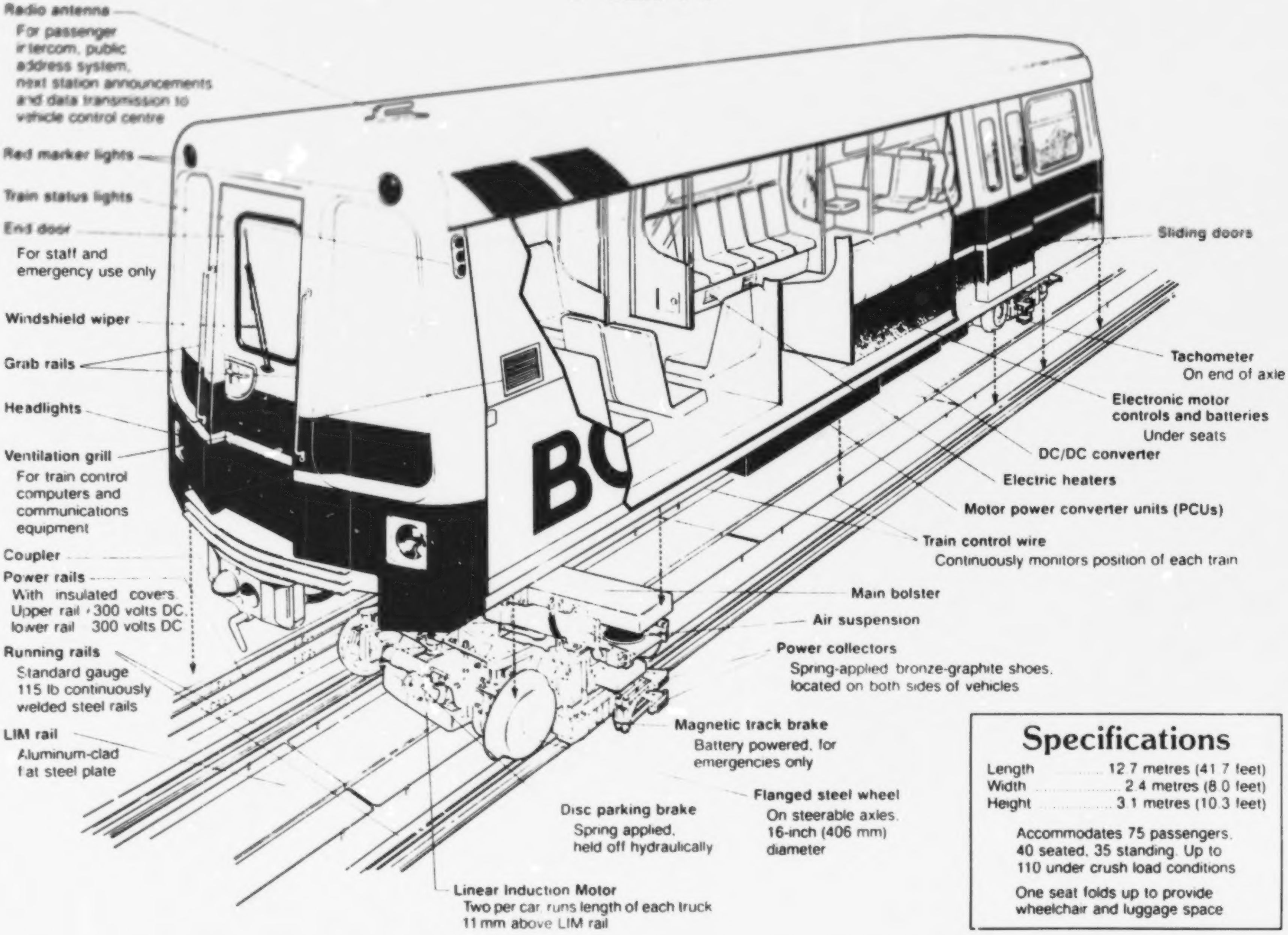
CALGARY/EDMONTON LRV


transit
transit
815
3807
1800
7720
1800
23054
7720
1800
3807
815
measurements in mm
1435
2650

SPECIFICATIONS

Manufacturer	Siemens/Duewag (Dusseldorf, Germany)
Model	U2 Light rail car
Type	Double-ended articulated car, 6-axle multiple-unit operation to 4 cars
Height (from Rail to Top of Car)	3.28 m
Width (Exterior)	2.65 m
Length (End to End)	23.05 m
(Over Coupler Faces)	24.28 m
Weight (Empty)	32.600 kg
Carbody Materials	Articulation and operator Lightweight welded cab operator covered by reinforced fiberglass
Braking	Dynamic braking device and 2 track brakes for each truck as well as disc brakes acting on 4 axles
Maximum Speed	80 km/h
Traction Power Supply	Overhead power, 600 Vdc
Passenger Capacity	64 seats per car. Comfortable capacity for 124 standees per car

ALRT


Radio antenna
For passenger intercom, public address system, next station announcements and data transmission to vehicle control centre
Red marker lights
Train status lights
End door
For staff and emergency use only
Windshield wiper
Grab rails
Headlights
Ventilation grill
For train control computers and communications equipment
Coupler
Power rails
With insulated covers. Upper rail +300 volts DC. lower rail 300 volts DC
Running rails
Standard gauge 115 lb continuously welded steel rails
LIM rail
Aluminum-clad flat steel plate
Sliding doors
Tachometer
On end of axle
Electronic motor controls and batteries
Under seats
DC/DC converter
Electric heaters
Motor power converter units (PCUs)
Train control wire
Continuously monitors position of each train
Main bolster
Air suspension
Power collectors
Spring-applied bronze-graphite shoes, located on both sides of vehicles
Magnetic track brake
Battery powered, for emergencies only
Flanged steel wheel
On steerable axles, 16-inch (406 mm) diameter
Disc parking brake
Spring applied, held off hydraulically
Linear Induction Motor
Two per car, runs length of each truck 11 mm above LIM rail
BC

Specifications

Length	12.7 metres (41.7 feet)
Width	2.4 metres (8.0 feet)
Height	3.1 metres (10.3 feet)

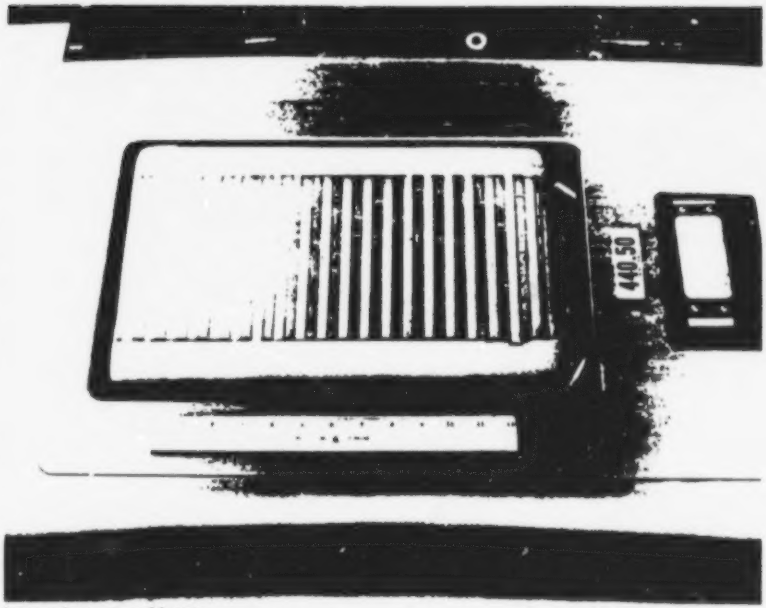
Accommodates 75 passengers, 40 seated, 35 standing. Up to 110 under crush load conditions

One seat folds up to provide wheelchair and luggage space

WEDWAY

The WEDway PeopleMover is driven by a linear induction propulsion system which efficiently translates thrust directly to the vehicle without intervening gears, belts, or other mechanical devices. Rectangular electrtomagnetic motors are attached to the roadbed between the two guide rails. The motors react upon an aluminum-faced steel platen plate which is mounted beneath each car.

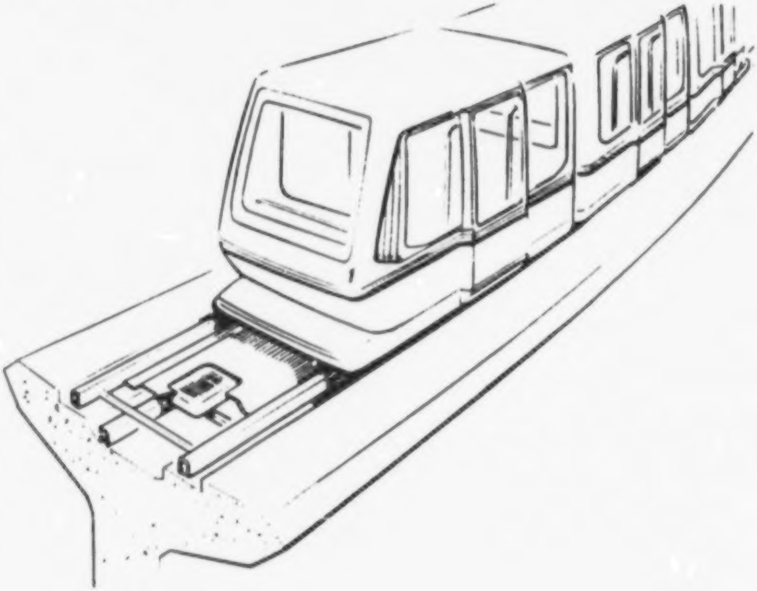
The motors are turned on by proximity sensors only when a platen approaches, providing thrust in either direction as required. Vehicle speed, which is determined by sensors adjacent to each motor, is regulated by the duration of power applied to each motor.



Linear Induction Motor

WEDway's track is constructed of structural steel tubing capable of containing power wiring. The track is bolted to a concrete or steel bed for support and rigidity. The motors, spaced between the track are shimmed to the correct height to provide the necessary motor/platen air gap clearance.

Although current vehicles travel on a relatively flat plane, they can be propelled on any angle depending on the power supplied to the motors. Passenger comfort limits track angle to approximately 15% and track curves to a minimum 20-foot radius.



WEDWAY (Cont'd)

SPECIFICATIONS (HOUSTON INSTALLATION)

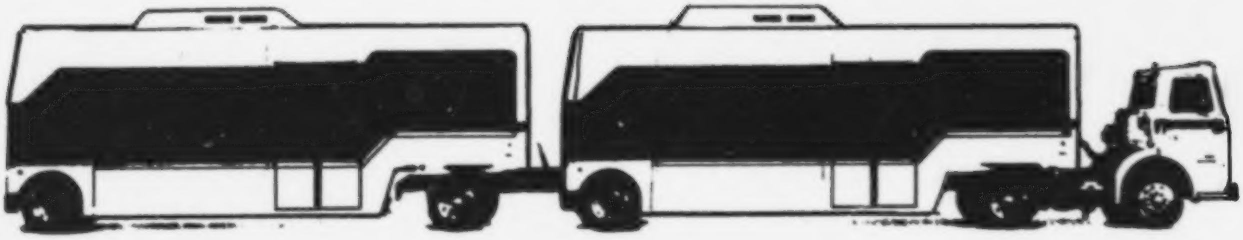
Maximum Theoretical One-way Capacity (passengers/hours)	1,680
Mode of Operation	Closed-loop
Reliability - 1983	99.9%
Operating Hours - 1983	7,844

Speed	Kph	25
Acceleration	m/s^2	1.0
Deceleration	m/s^2	1.3
Emergency Stop	m/s^2	3.6
Traction Requirement		NONE

Body Type	-	fully-enclosed
Wheel Base	mm	2,590
Overall Length	mm	4,100
Overall Width	mm	1,575
Overall Height	mm	2,340
Empty Weight	kg	1,100
Gross Weight	kg	2,000
Doorway Width	mm	1,070
Power Collection	-	NONE
Hydraulics	-	NONE
Passengers Per Car	-	12 with luggage
Cars Per Train	-	3
Train Capacity	-	36

Motor Type		-	Linear induction, active track motor, passive car platen
Motor Spacing			
Stations		mm	1000
Cruise Areas		mm	4000
Motor Rating -	Power	-	240V, 60Hz, 3 Phase
	Thrust	kg	60
Motor Control		-	Speed and Proximity Sensors operating through control logic
Braking -	Service	-	Linear Motor Reverse Polarity
	Station Docking	-	Mechanical
	Emergency Stop	-	Mechanical

SUPERBUS



SPECIFICATIONS

PASSENGER MODULE

Length - 8250, other lengths available
Width - 2590 or 2440
Height - 3430
Capacity - 29 passengers seated, 32 standing
Neway air suspension
Roof-mounted Sturak air conditioning and heating combination (optional)
Interior design can be built to specs, for utility or transit
Air-operated door
Emergency exit roof hatch
A/C auxiliary diesel engine
Side door entry floor height approximately 380
Converter dolly available for connecting two interchangeable passenger modules

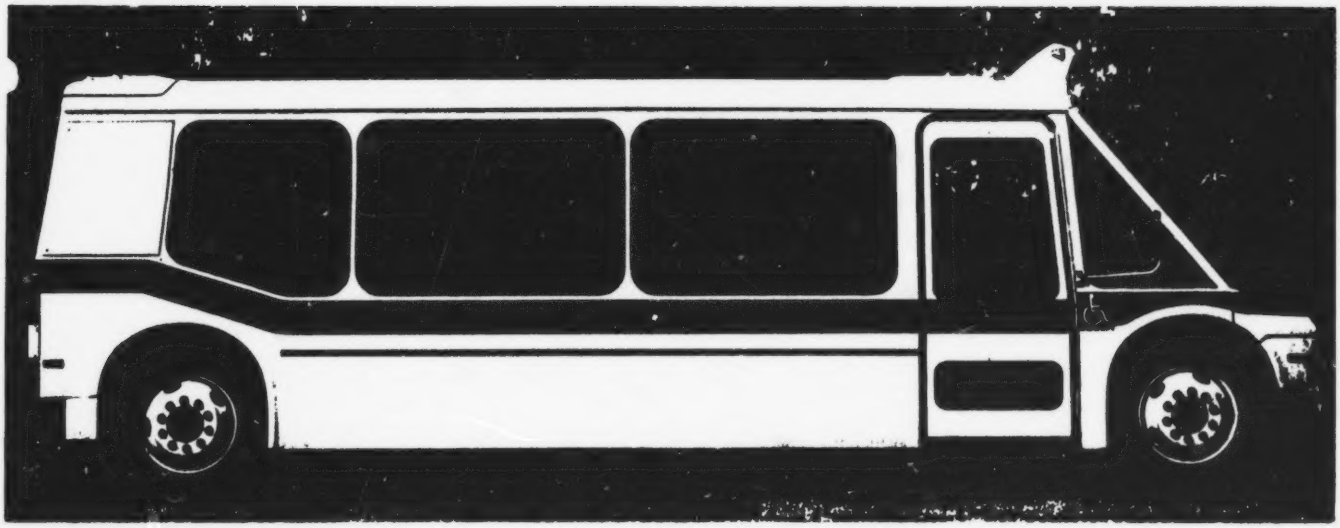
POWER MODULE

Operator may select any cab-over tractor available on the commercial market. Options would include types of engines and transmissions, wheel base, fifth wheel height, etc.

GENERAL

Two-way voice communication between driver and passengers, call box/speakers in passenger module
Easy hookup and disconnect of passenger module
Air-operated landing gear
Semi-articulated
Overall length of two passenger and one power module - 19.8 m

ORION II



SPECIFICATIONS

25' (7620 mm) model

DIMENSIONS

Length (over bumpers) 25' 11" (7899 mm)

Width 96" (2438 mm)

Height 100" (2540 mm)

Floor Height ("Normal Ride") 12" from ground (305 mm)

ENGINE

25' (7620 mm) - Detroit Diesel 8.2 liter 145 hp (108 kw) @ 2800 rpm

TRANSMISSION

Automatic Allison AT545

VEHICLE PROPULSION

Front wheel drive Helical reduction

AXLES

GKN 12000 lbs (544 kg) 5.38 ratio 56 mph (90 kmh) Optional ratios avaliable

WHEELS & TIRES

4 single tires 255/8)R 22.5 XYZ on 10 stud hub-mounted wheels 22.5 x 7.5"

REAR DOOR

SEATING CAPACITY

26 seated maximum plus driver

BODY STRUCTURE

Stainless steel integrated structure

Exterior Panels - Stainless steel and easily removable aluminum and fiberglass

Interior - RCA Rubber floors and melamine and vacuum-formed panelling

BRAKES

15.5" x 6" (394 mm x 152 mm) S-Cam full air, front and rear. Lining thickness 3/4" (19 mm)

ELECTRICAL

Two heavy duty 12 volt Group 31 batteries; Wiring is heavy duty flame resistant, color-coded and numbered

FUEL TANKS

(2) 21 Imperial gallons (94.6 liters)

HEATING

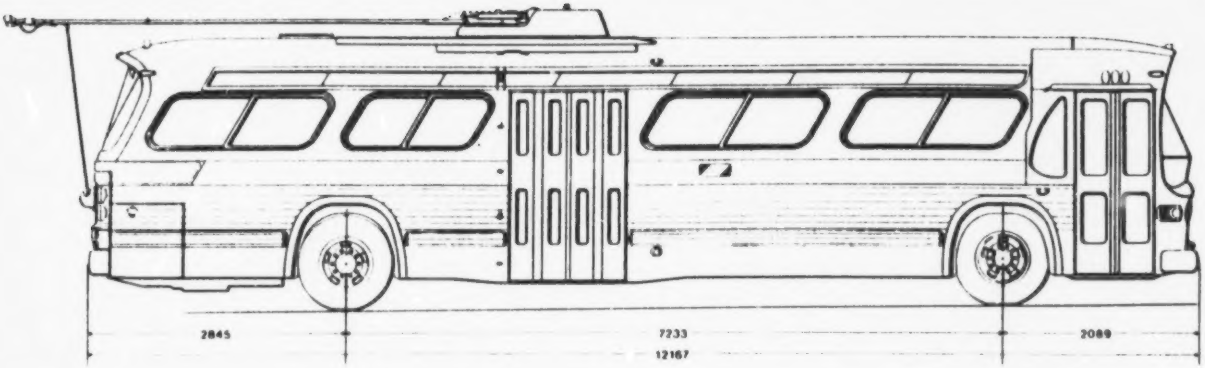
80000 BTU (20000 Kcal) combined front and rear

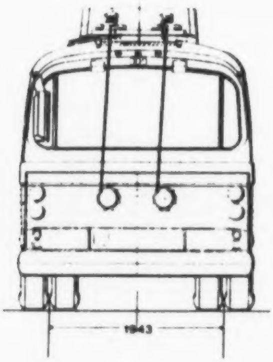
SUSPENSION

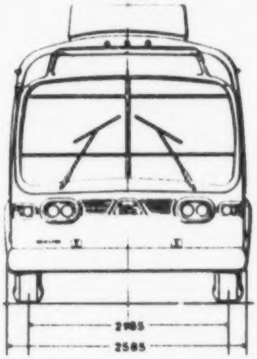
Front - Full air, tube axle
Rear - Full air, independent trailing arm

ROOF HATCH

TROLLEY BUS







TECHNICAL SPECIFICATION

HR 150 G

Specification for trollery bus as delivered to the City of Edmonton Transit

Propulsion	
Rated line voltage	600 V
Maximum line voltage	720 V
Minimum line voltage	420 V
Power at motorshaft	
maximum	269 kW (360 hp)
continuous	137 kW (184 hp)
Tractive effort	
maximum	31 kN (6969 lbs)
continuous	11.8 kN (2653 lbs)
Braking effort	
maximum	17 kN (3822 lbs)
Initial acceleration*	1.4 m/s^2 (3.15 mphps)
Time to accelerate from 0 to 50 km/h*	15 s
Maximum speed on level*	60 km/h (37 mph)
Maximum speed on 5% grade*	55 km/h (34 mph)

Weight	9700 kg (21,385 lbs)
Body	GM T6H 5307 N
Seating capacity	42

Optional Equipment Available:

- emergency drives (Batteries or thermal engine
- air conditioning

* with seated load

WESTINGHOUSE - PEOPLE MOVER

SPECIFICATIONS

VEHICLE:

Suspension Type	Primary suspension is by pneumatic tires
Lateral Guidance	Foam-filled tires running against guideway
Overall Length	11,180 mm
Overall Width	2,850 mm
Overall Height	3,355 mm
Empty Weight	11,700 kg
Gross Weight	23,000 kg
Total Passenger Area	23.9 m^2
Floor Area for Seated Passengers	0.9 m^2
Floor Area for Standing Passengers	23.0 m^2
Vehicle Design Capacity	2 seated; 92 standing at 4/m^2
Doorway Width	21,134 mm
Doorway Height	2,440 mm
No. of Doors per Vehicle	2 left side; 2 right side

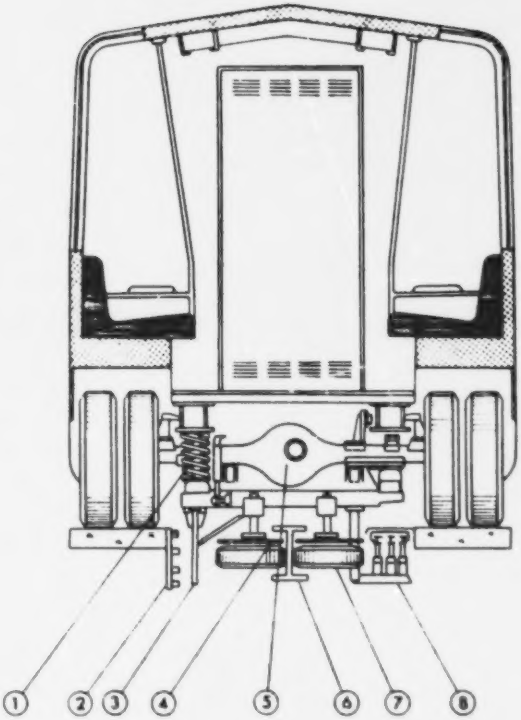
PROPULSION:

One series-wound dc motor per vehicle, axle mounted

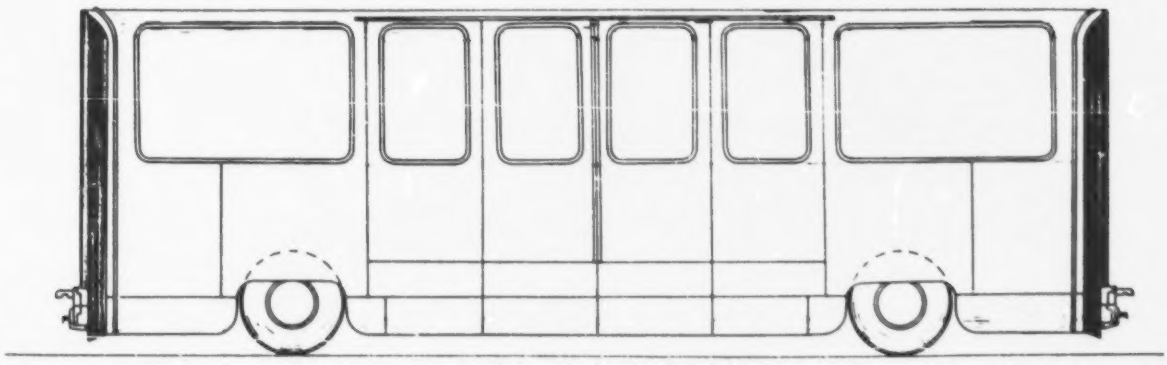
Motor Rating	75 kW at 1985 rpm
Type Power	500 Vdc
Power Collection	480 Vac, 3-phase through collector shoes
Type Service Brakes	Dynamic braking blended with electropneumatic friction brakes (drum)
Type Emergency Brakes	Pneumatic spring held-off, drum

GUIDEWAY:

Running Surface Width (per double tire)	550 mm
Max. Grade	3.8%
Min. Horiz. Turn Radius	198 m at 48 km/h



1 Air and steel spring comb.
2 Signal wire system
3 Receiving and transmitting antenna
4 Safety disk
5 Differential and hypoid drive.
6 3 Phase collector system.
7 Pneumatic guide tire.
8 Steel guide rail.



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Goetz Heidelberg and Johannes Pleger

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The M-BAHN – a magnetically suspended short-haul transport medium

1. General observations on the choice of this system

Contactlessly suspended and -driven guided vehicles have long been the aim of transport technologists because contactless running eliminates wear and tear, and thus reduces both costs and environmental pollution to a minimum. Hovertrains have been found unsuitable for this purpose; but magnetic suspension and guidance technologies are being explored along various lines of development by several groups of companies in a number of countries. Some of these developments have now reached the stage of extensive full-scale passenger-carrying trials.

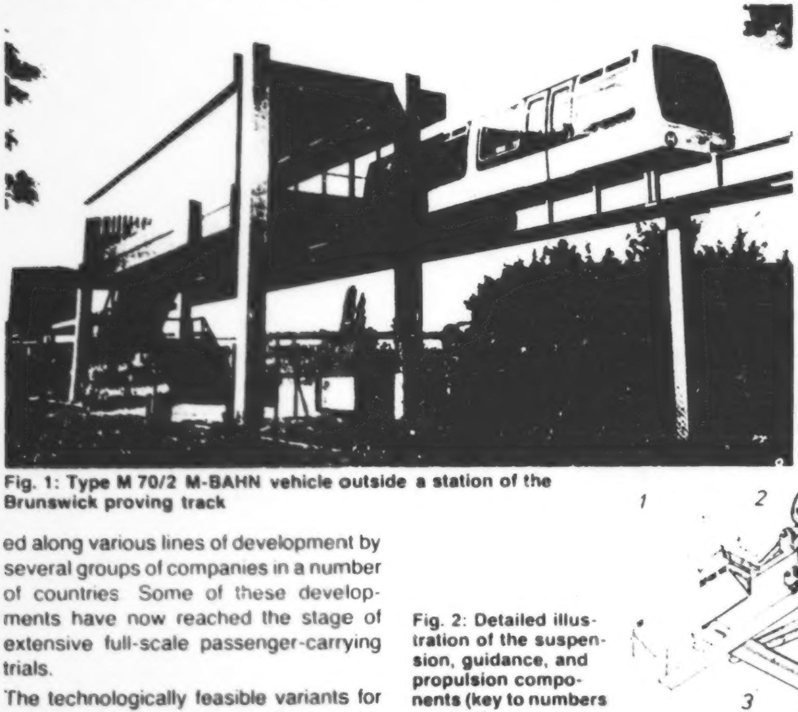


Fig. 1: Type M 70/2 M-BAHN vehicle outside a station of the Brunswick proving track

The technologically feasible variants for maglev vehicles are the result of combinations of the various suspension and guidance systems with all the versions of the linear motor. For the required investment and therefore the economic viability of the whole installation it is essential that the chosen principle should allow the use of identical structural elements for the suspension as well as for the linear motor. Of further importance is arrangement of the active part of the linear motor either in the vehicle or on the track.

The main variants of suspension are

▷ attractive, controlled electro-magnets under an iron armature,

▷ electro-magnetic levitation by means of strong magnetic fields above a conductor, in which eddy currents are induced by the movement of the vehicle magnet,

▷ the utilization of the repellent force of homopolarly arranged permanent magnets, and

▷ attractive permanent magnets, also under an iron armature, with a mechanically controlled air gap.

The linear motor can be designed

▷ in short-stator construction with the active part requiring propulsion energy in the vehicle, or

▷ as a long-stator motor with the winding producing the travelling wave for the thrust generation on the track and only the armature with its excitation in the vehicle.

In either case construction as a synchronous or as an asynchronous motor is possible.

The development aim of the electrodynamic and electromagnetic system is as a rule long-distance transport; for reasons of weight a long-stator motor, i. e. with a travelling-wave winding on the track, is used. In the more distant future such systems may close the gap in the market, provided there is sufficient call for them, between the possibilities of the wheel-on-rail technology and of air transport. As far as we know, short-haul concepts of these technologies have not been pursued on a major scale, particularly perhaps because short-haul transport is unprofitable in practically every country, and therefore unable to finance the necessary new development and the resulting investment; moreover, mature systems, economical because of their scale, are available for both road and rail transport.

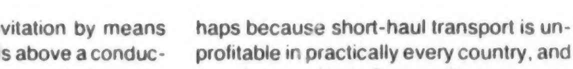


Fig. 2: Detailed illustration of the suspension, guidance, and propulsion components (key to numbers see text)

The concept of the M-BAHN (Fig. 1) has

Dipl.-Phys. Götz Heidelberg, Geschäftsführer, Magnetbahn GmbH, Moosstraße 14, D-8130 Starnberg, and Dipl.-Ing. Johannes Pleger, Magnet-Motor GmbH, Petersbrun-

of 1.2m/sec². It also functions as a parking brake during halts.

3. The guideway

The structural elements and the function of the track (Fig. 5) are implicit in the description of the elements of the suspension, guidance, and propulsion technologies. These elements can be structurally simply arranged between rolled girders (12), welded girders, framework-, in situ concrete, and prestressed concrete structures. Access footpath for maintenance, which serves also as an escape (Fig. 3/13), is provided simply and unobtrusively between the girders. The overall height is 0.8 to 1.6m with unsupported girder lengths between 8 and 35m. This low height of the supporting structure, the result of light loads per m and of the absence of individual point loads from the vehicles, permits the introduction of economical overall solutions conforming to high standards of urban planning.

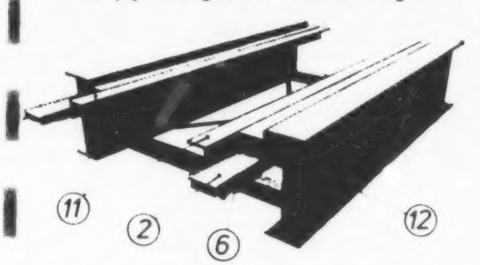


Fig. 5: Section through the guideway

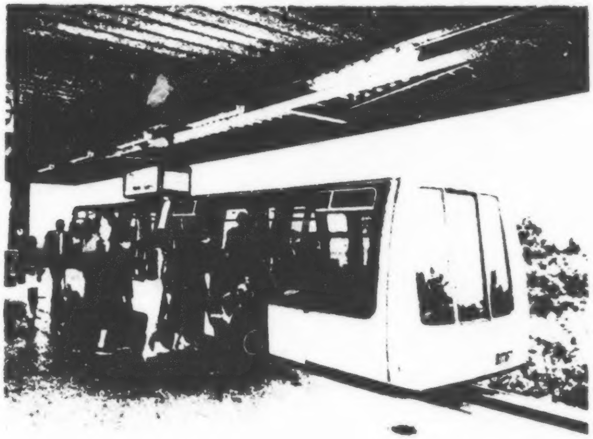


Fig. 6:
Station with vehicle

The points function through the swivelling of a length of the guide rails. In the interest of simplicity of construction a one-sided interruption of the normal support and drive function is permissible at the speeds required.

In these favourable load conditions spandrel-braced track construction with prefabricated steel-, reinforced concrete-, or sheet-steel box girders poses no problems. In station sections and for local coordination with other transport modes jibs or portal supports of various widths can be used. Stations present no system-specific characteristics (Fig. 6). The type of track construction allows open platform edges as in conventional short-haul transport systems.

The dynamics of vehicle movement are determined, as with conventional railways, by the acceleration the passengers will tolerate. They correspond to the usual data, but unlike in the wheel-on-rail technology, no limits are imposed on climbing ability by a coefficient of adhesion adversely affected by weather conditions, dirt on the rails, etc.

4. Power supply

A standardized converter is provided for the track sections, whose lengths, between 100 and 300m, are determined by the power requirements. The converters, each for a few km of line, are centred in sub-stations, from where they selectively supply the sections of line occupied by the train through cables and switch gears.

The substations receive their power from the public medium-voltage grid.

The basic switch gear consists of a three-phase transformer with a short-proof, self-ventilating semiconductor rectifier, a d. c. bus bar, and the pulse converters, which supply the three-phase current of variable voltage and frequency for the track sections.

5. Operation

For the operation of driverless automatic train units and unmanned stations an operational management system has been evolved which contains various function groups and -levels. These comprise

▷ the operational management centre with its staff,

▷ the operational control centre on the operational level, equipped with a computer for automatic operation, disposition, and train control,

▷ the control of the converters and of the supply of the track sections according to the instructions from train control, as well as

▷ a train protection system independent of the above-mentioned levels and functioning parallel to the automatic operational control, which monitors adherence to the safety criteria and actively intervenes only in conflict situations.

The operational management centre automatically receives all the important operational data, which it processes for display on an illuminated track diagram or on monitors. From here it is possible to intervene in the fully automatic operation, which is carried out by the operational control centre with its computer equipment through the setting of the regular-interval running, the issue of the departure commands, component monitoring of the entire installation and especially of the interfaces for train control, train protection, and data transfer.

The safety system monitors, continuously and independently of the operating control, the relevant factors such as distance from points of conflict, maintenance of set speeds, route locking, control of the train set, safety of passenger movement in the stations, and especially the control of the emergency braking system and, if necessary, automatic application of the spring double-jaw brake.

A breakdown strategy laid down in detail minimizes the adverse effect on operation of any fault – depending on the extent and location of the damage causing it.

6. Future prospects and summary

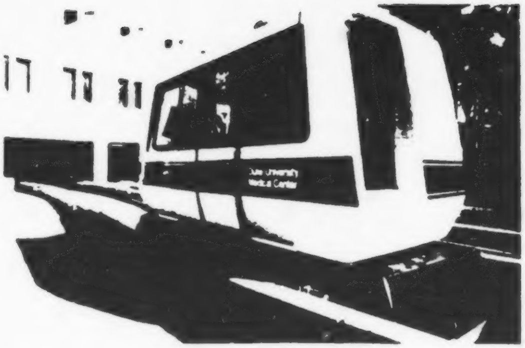
It is the objective of the newly-developed maglev system named M-BAHN to offer a transport medium for traffic volumes below those of an S-bahn or heavily-loaded underground railway which does not call for the very high prime and operating costs of these two systems. This is achieved through the linking of the following individual innovations.

1. Simple and light-weight vehicles of reduced power consumption owing to the elimination of an active propulsion unit in the vehicle.
2. Linear load transfer and light line loads allow the use of a simple track structure.
3. The compact cross section of vehicles

HOVAIR

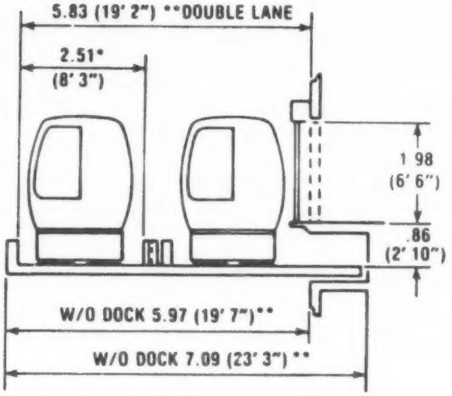
SYSTEM DESCRIPTION

The Otis Hovair is a versatile automated system in the light guideway class. It was developed specifically to fit into highly congested sites to move people and cargo between and within buildings, horizontally and vertically, in a compatible, space-efficient manner.

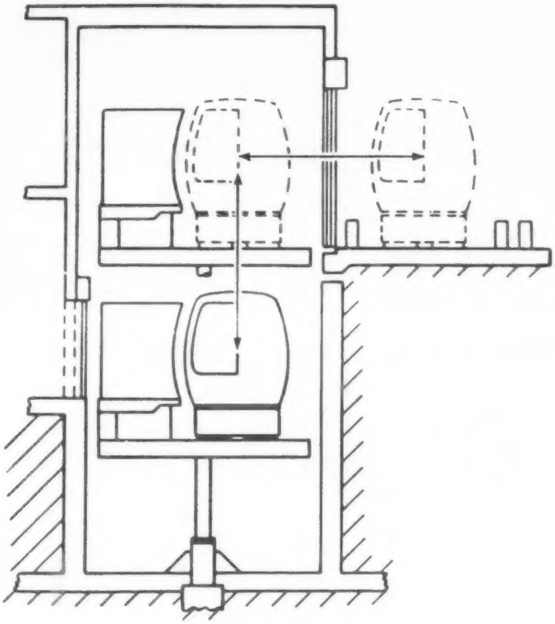


The space saving feature is achieved by using vehicles equipped with HOVAIR air film pad suspension and electromagnetic (LIM) propulsion and braking systems. This gives the vehicles an essentially frictionless omnidirectional capability. It provides ease of steering and switching and permits direct lateral movement for compact off-line passenger loading, lane transfers, or transfer onto an elevator for vertical transport to a different elevation within buildings or complexes. All of these features are currently used in the Otis Network Transit system at the Duke University Medical Center in Durham, North Carolina.

Exclusive trough-shaped guideways of about nine feet overall width are employed using standard steel or concrete construction.



CLEARANCES

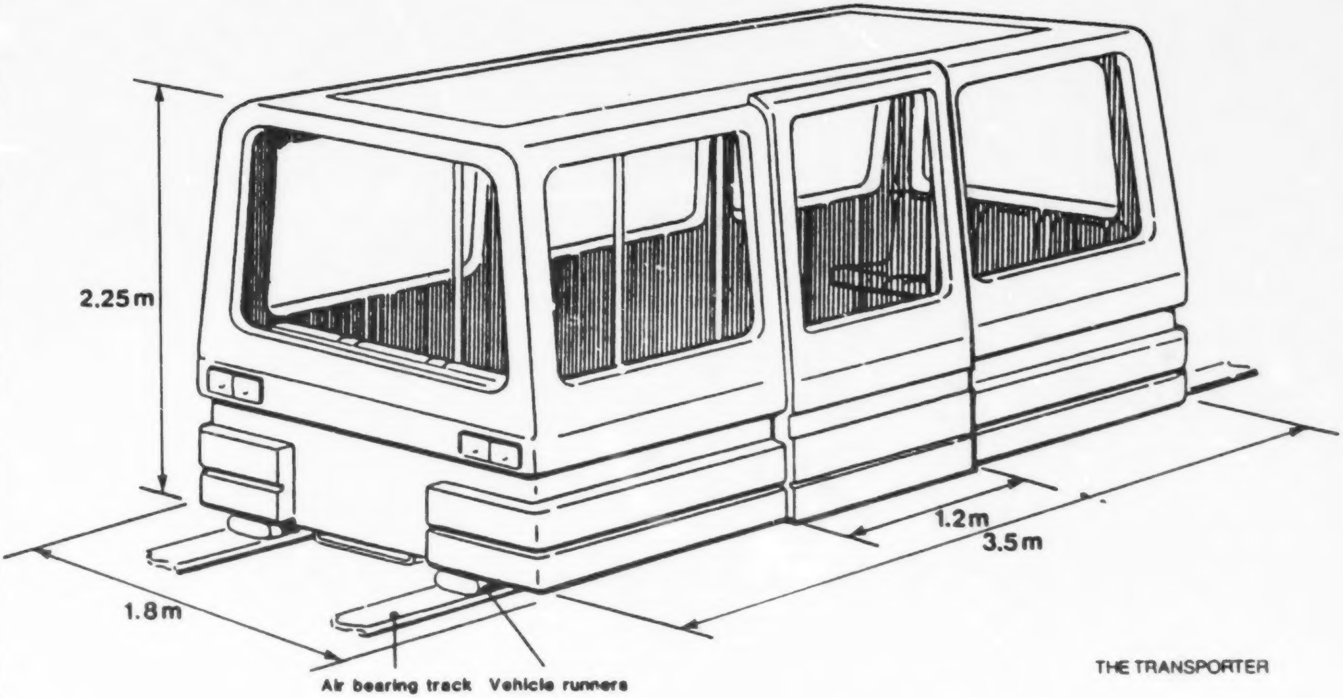


LATERAL/VERTICAL TRANSFER

SPECIFICATIONS

Passenger per vehicle	29	Acceleration/Deceleration m/s^2	1.0
Line Capacities	600 - 800 per hour	Emergency Deceleration m/s^2	2.5
Vehicle size m	2.25W -2.9H -4.6L	Normal Braking	Electormagnetic regenerative
Empty weight, kg	4800	Emergency Braking	Friction skids
Line speed, km/h	64	Power Supply	480V,3PH,60HZ Other voltages as required.
Maximum recommended grade,	6%		

TRANSPORTER


2.25m
1.8m
1.2m
3.5m
Air bearing track
Vehicle runners

THE TRANSPORTER

SPECIFICATIONS

Length	3.5 m
Width	1.8 m
Height	2.2 m
Inside Height	2.0 m
Vehicle Weight empty	1000 kg
Vehicle Weight with 16 passengers at $4/m^2$	2200 kg
Crush loading (22 at $6/m^2$)	2650 kg
Design speed	5 m/s
Maximum acceleration and deceleration	$1.0 \ m/s^2$
Emergency deceleration	$1.5 \ m/s^2$

APPENDIX A - 3

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APPENDIX B

PARTIAL LIST OF MANUFACTURERS

B-1 Product Type
B-2 Addresses

APPENDIX B-1
PARTIAL LIST OF MANUFACTURERS
PERSONNEL AND MATERIALS TRANSPORT EQUIPMENT
BY PRODUCT TYPE

Name	Product
Abex Corp. (Railroad Products Group)	Conveyors, track and accessories
AEC Inc., (Alpine)	Conveyors, locomotives
A & K Railroad Materials Inc.	Track and accessories
Allens of Tipton Ltd.	Hoisting equipment, shuttle cars, mine cars
American Construction Equipment Group	Cranes
American Mine Door Co.	Track and accessories
American Motors Corp.	Trucks
Anderson-Strathclyde PLC	Conveyors, track and accessories
Andrew Merrilees Ltd.	Mine cars
ARA (Toro)	LHD's, FSV's
ASEA Inc.	Hoisting equipment, locomotives, mine cars
Atlantic Track & Turnout Co.	Track and accessories
Atlas Car (Marmon Group)	Mine cars, locomotives
Babcock Allatt Limited	U/G graders
Babcock Mining Services	Conveyors
Baycar Steel Fabricators Ltd.	FSV's, mine cars
Becorit (G.B.) Ltd.	Conveyors, engines, monorails, locomotives, FSV's
Bedia GmbH & Co.	Locomotives, cranes
Bethlehem Steel Corp.	Track and accessories
Black Box Radio Controls Limited	Monitoring and control
Bridgestone Tire Co. Ltd.	Rubber tires
British Jeffrey Diamond	FEL's, FSV's
Brookville Locomotive Div.	Locomotives
Brush Transformers Ltd.	Conveyor equipment
BTR Ltd.	Conveyors
Cable Belt Ltd.,	Conveyors
Canadian General Electric	Electrical hoisting equipment
Canron Inc. (WABD	Mine cars
Card Equipment Co.	Locomotives, mine cars
Case Co. J.I.	Cranes, FEL's, forklifts
Caterpillar Tractor Co.	Engines, FEL's, FSV's, forklifts
Champion Road Machinery	Graders
Clark Equipment Co. (Bobcat)	FEL's, forklifts
Communication & Control Eng. Co. Ltd	Track and accessories, monitoring and control
CONSPEC Controls Inc.	Monitoring and control
Continental Conveyor (BF Goodrich)	Conveyors
Cummins Engine Co. Inc.	Engines
Cushman/OMC Lincoln	FSV's
DAC Limited, (Dacon Works)	Radio communications
Danmer Equipment Company	Mine cars
Deilmann-Haniel GmbH	Conveyors, monorails, FSV's, hoisting equipment, winches, monitoring and control
Detroit Diesel Allison	Engines
Difco Inc.	Mine cars
Dipl.-Ing. TH. Steinfurth GmbH	Trolley accessories
DJB Engineering Ltd.	FSV
Dorr-Oliver Canada Ltd.	Mine cars

APPENDIX B-1 (Continued)
PARTIAL LIST OF MANUFACTURERS
PERSONNEL AND MATERIALS TRANSPORT EQUIPMENT
BY PRODUCT TYPE

Name	Product
Dowty Meco Ltd.	Conveyors
Duesterloh Gmbll G	Winches, ski-lifts, FSV's, mine cars
Dunlop Belting Ltd.	Manriding conveyors
Dux Machinery Corporation	Cranes, forklifts, FSV's, LHD's
Eaton Corp Industrial	Hoisting equipment
Eickhoff Gm BH	Manriding conveyors
Electro-Life Battery Co.	Batteries
Eimco Mining Machinery International	Engines, cranes, FEL's, FSV's, LHD's
Emae	Conveyor equipment
Fairchild Inc.	Conveyors, mine cars, FSV's, rail vehicles
Femco Div., Gulton Industries Inc.	Communications, monitoring and control
Fletcher Sutcliffe Wild Ltd.	Conveyors
FMC of Canada Ltd.	Conveyors, cranes, rail vehicles, FEL's, LHD's, shuttle cars, mine cars
Forano Inc.	Conveyors
Ford Motor Co. of Canada	Engines, trucks
Foster Co. L.B.	Track and accessories, mine cars
France Loader (L-Equipment Minier)	Engines, cranes, FSV's, LHD's, forklifts
Funke & Huster	Monitoring and control
GEC Canada Ltd.	Conveyors, hoisting equipment, engines, locomotives
General Battery Corporation	Batteries
General Motors of Canada Ltd.	Engines
George Moss Pty Ltd.	Locomotives, FSV's, LHD's, shuttle cars, track and accessories
Getman Corp.	Engines, cranes, rail vehicles
Goodman Equipment Corp.	Locomotives, shuttle cars, rail vehicles
Goodyear International Corp.	Conveyor belts, rubber tires
Gordon Russell Ltd.	Remote control
Gould Manufacturing Co.	Batteries
Greengate Industrial Polymers	Conveyor belts
Greening Donald Co. Ltd.	Hoisting equipment
Grove Manufacturing Company	Cranes
Gyro Mining Transport Ltd.	Engines, locomotives, rail vehicles
Hawker Siddeley Group (Dosco, Noyes)	Engines, locomotives, shuttle cars, track and accesories, FSV's
Hepburn Ltd., John T.	Hoisting equipment
H.K. Porter, Inc.	Track [illegible]
Hudson Ltd. Robert	Track and accessories, mine cars
Hunslett (Hunslett Engine Works)	Locomotives
Huwood Ltd.	Conveyors, electrical equipment, monitoring and control
Huwood-Irwin Co.	Mine cars, rail vehicles, FSV's
Industrialexportimport, Foreign Trade Co.	Conveyors, hoisting equipment, locomotives
Ingersoll-Rand Mining Machinery	Engines, cranes, FEL's, FSV's, LHD's
In-Pro Corp.	Locomotives, mine cars, FSV's
Isuzu Diesel North America Inc.	Engines, trucks
Jarvis Clark Co. Ltd.	FEL's, personnel carries, material carriers
Jeffrey Mining Mfg. (Dresser)	Conveyors, locomotives, shuttle cars

APPENDIX B-1 (Continued)
PARTIAL LIST OF MANUFACTURERS
PERSONNEL AND MATERIALS TRANSPORT EQUIPMENT
BY PRODUCT TYPE

Name	Product
John Deere Construction Equipment	Engines, FEL's, forklifts
Joy Manufacturing Co.	Conveyors, hoisting equipment, shuttle cars
Kaelble, GmbH Carl	FEL's, locomotives, FSV's, graders
Kersey Manufacturing Co.	FSV's, rail vehicles
Kleber Industrie	Conveyor equipment
Klochkner-Humboldt-Deutz AG	Engines
Kloeckner-Becorit North America Inc.	Monorails, locomotives, chair lifts, winches
Kopex, Export-Import	Conveyors
Krampe & Co.	Conveyors, monorails, chair lifts
Krupp GmbH Canada Inc.	Conveyors, cranes
Kubota Tractor Canada Ltd.	Tractors
Lake Shore Inc.	Hoisting equipment, mine cars
Lead Industries Assoc. Inc.	Batteries
Lebus International Engineers Inc.	Hoisting equipment
Long-Airdox Co., (Marmon Group)	Manriding conveyors, mine cars, FSV's, rail vehicles
MAN (GHH) Canada Inc.	Winches, FSV's, conveyors, engines, cranes, FEL's, hoisting equipment, LHD's, mine cars
Mannesman Demag Ltd.	Cranes, hoisting equipment, winches
Marathon Letourneau Co.	Cranes, FEL's
Markham & Co. Ltd.	Hoisting equipment winches
Material de Fond d'Industrie	Locomotives, winches, monorails
McJunkin Corporation	FSV's
Mercedes-Benz Canada Inc.	Engines, trucks
Michelin Tire Corp.	Rubber tires
Miltor Drilling Equipment Ltd.	FSV's
Mine Equipment Co.	FSV's
Mine Safety Appliance Co.	Monitoring and control
Minejack Mining Equipment	FSV's (graders U/G)
Mines de Potasse D'Alsace	FSV's
Mining Transportation Co. AB (Kiruna)	FSV's
Monninghoff GmbH & Co. KG	Brakes
Mouty-Bonehill	Mine cars, rail vehicles
Mitsui Miike Machinery Co.	Manriding conveyors, hoisting equipment, rail vehicles
MWM Motoren-Werke Mannheim AG	Engines
National Mine Service Co.	Locomotives, shuttle cars, mine cars, trolley equipment, monitoring & control
Neeham Bros. and Brown Ltd.	Hoisting equipment
NEI Mining Equipment Ltd. (Clayton)	Locomotives
Neuhaeuser GmbH & Co.	Conveyors monorails
O & K Canada (Costello)	Conveyors, cranes, FEL's, hoisting equipment, walking belts, forklifts
Ohio Brass Co. (Ind. Products Div.)	Locomotives, track and accessories, monitoring and control
Oldhan Batteries Ltd.	Batteries
Pettibone Corp.	Cranes
PHB Weserhuette AG	Conveyors, cranes, hoisting equipment, monorails, chairlifts
Pikrose & Co. Ltd. (Marmon Group)	Hoisting equipment
Plymouth Locomotive Works, Inc.	FEL's, locomotives
Precismeca Canada Ltd.	Conveyors
Qualter Hall & Co.	Hoisting equipment

APPENDIX B-1 (Continued)
PARTIAL LIST OF MANUFACTURERS
PERSONNEL AND MATERIALS TRANSPORT EQUIPMENT
BY PRODUCT TYPE

Name	Product
REI (Realisation Equipements Industriels)	Conveyors
Rexnord Canada Ltd. (Nordberg)	Conveyors, hoisting equipment
Ruhrthaler Schwartz & Dyckerhoff KG	Locomotives, monorails
Saab-Scania AB	Engines, track accessories
Safetran Systems Corp.	Track accessories
Safety Supply Canada	Monitoring and control
Samiia	Hoisting equipment, winches
Sanford-Day (Marmon Group)	Mine cars, rail vehicles
Scharf Co.	Hoisting equipment, monorails, winches, locomotives
Schopf Maschinenbau GmbH	FEL's, personnel carries, LHD's
Schroeder Bros. Corporation	FSV's
Sheepbridge Equipment Ltd.	Mine cars
Siemag Transplan GmbH	Hoisting equipment, winches
Silec DSI	Monitoring and control
Societe Stephanoise de Constructions	Locomotives, monorail, conveyors
Stancanada Inc. (USSR)	Locomotives, personnel carriers, material carriers
Strojexport, Foreign Trade Corp.	LHD's, mine cars, rail vehicles
TBA Industrial Products Limited	Conveyor belting
TDI Turbostart (Western)	Engine starters
Teledyne Canada Mining Products	Cranes, personnel carriers, material carriers
Thyssen (Great Britain) Ltd.	Conveyors, hoisting equipment, winches
Timberland Equipment Ltd.	Hoisting equipment
Toyo Kogyo Co. Ltd.	Engines, trucks
Toyota Industrial Sales (EMS)	Engines, trucks
UMM Ltd.	Cranes, monorails, locomotives, personnel carriers
VOEST-Alpine AG	Conveyors, FEL's, hoisting equipment, locomotives, winches
Volvo BM AB	FEL's, FSV's
Wagner Mining Equipment Co. (RIVQUIP)	LHD's, FSV's
Westinghouse Electric Corp.	Hoisting equipment
Wheway Watson Holdings Ltd.	Cranes
Whiting Corp. Trackmobile Div.	Locomotives
Wilderob Equipment Co.	Locomotives
Wilson R.M. Co. Inc.	FSV's
Wilson Manufacturing Co. Inc.	FSV's
Wire Rope Industries Limited	Hoisting equipment
Wolff Maschinenfabrik GmbH Emil	Hoisting equipment, winches

APPENDIX B-2
PARTIAL LIST OF MANUFACTURERS
PERSONNEL AND MATERIALS TRANSPORT EQUIPMENT
ADDRESSES

Name	Address	Postal Code	Telephone
Abex Corp. (Railroad Products Group)	200 South Michigan Ave., Chicago, Illinois	60604	800-222-2239
AEC Inc., (Alpine)	Box 106, State College, Pennsylvania	16801	814-238-1114
A & K Railroad Materials Inc.	Box 30076, Salt Lake City, Utah	84130	801-974-5484
Allens of Tipton Ltd.	Box 4, Tipton, W Midlands, England,	DY4 3EX	021-557-3977
American Construction Equipment Group	63 SO Robert St., St. Paul, Minnesota	55107	612-293-4567
American Mine Door Co.	Box 6028, Station B, Canton, Ohio	44706	216-454-7055
American Motors Corp.	27777 Franklin Rd., Southfield, Michigan	48034	313-827-3937
Anderson-Strathclyde PLC	47 Broad St. Glasgow, Scotland,	G40-2QW	041-5541800
Andrew Merrillees Ltd.	Old Weston Rd., Toronto, Ontario	M4H 3A5	416-656-1333
ARA (Toro)	St 20101 Turku 10, Finland		358-21-383111
Arbel Industrie	F59506 Douai Cedex, France		27-88-3311
ASEA Inc.	10300 Henri Bourassa W., St. Laurent, Quebec	H4S 1N6	514-332-5350
Atlantic Track & Turnout Co.	One Woodfield Lake, Schaunburg, Illinois	60195	800-323-6256
Atlas Car (Marmon Group)	Box 1511, Knoxville, Tennessee	37901	615-525-6224
Babcock Allatt Limited	1100 Finch Ave. West, Downsview, Ontario	M3J 2E3	416-661-2000
Babcock Mining Services	Newcastle, Tyne & Wear, England	NE44NG	
Baycar Steel Fabricators Ltd.	2151 Highway 69 South Sudbury, Ontario	P3E 4N1	705-522-0810
Becorit (G.B.) Ltd.	Hallam Fields Road, Ilkeston, Derbyshire, England	DE74BS	0602-302603
Bedia GmbH & Co.	Postf 103, 5300 Bonn I, Fed. Rep. Germany		(0228) 6682-360
Bethlehem Steel Corp.	Martin Tower, Bethlehem, Pennsylvania	18016	215-694-2424
Black Box Radio Controls Limited	Box 40, Norval, Ontario	L0P 1K0	416-877-0141
Bridgestone Tire Co. Ltd.	10-1, 1-Chome, Kyobashi, Chuo-Ku, Tokyo 104, Japan		
British Jeffrey Diamond	Thornes Works, Wakefield, W. Yorkshire, England	WF2 8PT	(0924) 375133
Brookville Locomotive Div.	Box 130 Brookville, Pennsylvania	15825	814-849-7321
BTR Ltd.	Centurion Way, Leyland, Lancs., England,	PR5 2RE	
Cable Belt Ltd.,	Yorktown House, Camberley, Surrey, England	GU15 3HS	
Canadian General Electric	107 Park St. N., Peterborough, Ontario	K9J 7B5	705-742-7711
Canron Inc. (WABI)	Box 1510, New Liskeard, Ontario	P0J 1P0	705-647-4383
Card Equipment Co.	Box 19518, Denver, Colorado	80219	303-922-2511
Case Co. J.I.	700 State St., Racine, Wisconsin	53404	414-636-6011
Caterpillar Tractor Co.	100 N.E. Adams, St., Peoria Illinois	61629	309-675-1000
Champion Road Machinery	107 McQueen St., West Columbia, South Carolina	29169	803-791-5200
Clark Equipment Co. (Bobcat)	112 N University, Fargo, North Dakota	58102	701-293-[illegible]
Communication & Control Eng. Co. Ltd.	Park Rd., Calverton, Nottingham, England	NG14 6LL	
CONSPEC Controls Inc.	44 Martin Ross Avenue, Downsview, Ontario	M3K 2K8	416-661-0500
Continental Conveyor (BF Goodrich)	Box 400, Winfield, Alabama	35594	205-487-6492
Cummins Engine Co. Inc.	Box 3005, Columbus, Indiana	47201	812-377-5000
Cushman/OMC Lincoln	Box 82409, Lincoln, Nebraska	68501	402-475-9581
DAC Limited, (Dacon Works)	Shobnall Street, Burton-on-Freist, Staffs, Eng.		0283-43421
Danmer Equipment Company	1501 Carling Ave., Ottawa, Ontario	K16 7M1	613-729-5145
Deilmann-Haniel GmbH	Postf 4600, Dortmund 13, Fed. Rep. Germany		0231-28910
Detroit Diesel Allison	13400 W Outer Driver, Detroit, Michigan	48239	313-592-5000
Difco Inc.	Box 238, Findlay, Ohio	45840	419-422-0525
Dipl.-Ing. TH. Steinfurth GmbH	43 Essen, Gudulastrasse 5, West Germany		RUF796446
DJB Engineering Ltd.	Peterlee, Durham, England,	SR8 2HX	
Dorr-Oliver Canada Ltd.	West St. 5, Orillia, Ontario	L3V 6Z4	705-325-6181

APPENDIX B-2 (Continued)
PARTIAL LIST OF MANUFACTURERS
PERSONNEL AND MATERIALS TRANSPORT EQUIPMENT
ADDRESSES

Name	Address	Postal Code	Telephone
Dowty Meco Ltd.	Meco Works, Worcester, England,	WR2 5EG	
Duesterloh GmbH G	Postf 1160, D-4322 Sprockhoevel, Fed. Rep. Germany		
Dunlop Belting Ltd.	Box 7 Liverpool, England	L24 1UY	
Dux Machinery Corporation	Box 80, Repentigny, Quebec	J6A 5H7	514-581-8341
Eaton Corp Industrial	9921 Clinton Rd., Cleveland, Ohio	44144	216-523-4796
Eickhoff Gm BH	Postf 100629, D-4630 Bochum, Fed. Rep. Germany		
Electro-Life Battery Co.	1225 East 40th St. Chattanooga, Tennessee	37407	015-867-4750
Eimco Mining Machinery International	Box 1211, Salt Lake City, Utah	84110	801-531-6000
Eimac	Rue Bara, 142 1070, Brussels, Belgium		604-687-9611
Fairchild Inc.	Box 1184, Beckely, West Virginia	25802	304-255-2131
Femco Div., Gulton Industries Inc.	2000 Bethel Dv. High Point, North Carolina	27261	919-887-2611
Fives-Cail Babcock	7 Rue Montalivet, 75383 Paris, France		1-266-3525
Fletcher Sutcliffe Wild Ltd.	Universal Works, Hornbury, Wakefield, Yorsk. England,		
FMC of Canada Ltd.	60 Bently St., Markam, Ontario	L3R 3L2	416-475-7500
Forano Inc.	1600 St. Paul St., Plessiville, Quebec	G6L 2Y9	819-362-7361
Ford Motor Co. of Canada	Oakville, Ontario	L6J 5E4	416-845-2511
Foster Co. L.B.	3 Riverway, Suite 1100, Houston, Texas	77056	713-626-1500
France Loader (L-Equipment Minier)	50 Ave., Victor Hugo, F-75117, Paris, France		
Funke & Huster	Postf 10 12 53, D-4300 Essen 1, Fed. Rep. Germany		0201-22091
GEC Canada Ltd.	150 Consumers Rd., Willowdale, Ontario	M2J 1P9	416-494-4330
General Battery Corporation	Box 1262, Reading, Pennsylvania	19603	215-378-0611
General Motors of Canada Ltd.	Box 5160, London, Ontario	N6A 4N5	519-452-5214
George Moss Pty Ltd.	Box 136, Mt. Hawthorn 6016 Australia		
Getman Corp.	Box 70, Bangor, Michigan	49013	616-427-5611
Goodman Equipment Corp.	4834 South Halstead St., Chicago, Illinois	60609	312-927-7420
Goodyear International Corp.	1144 E Market St., Akron, Ohio	44316	216-796-2121
Gordon Russell Ltd.	7600 Alderbridge Way, Richmond, British Columbia	V6X 2A2	604-270-1611
Gould Manufacturing Co.	275 Lewis St., Fort Erie, Ontario	L28 5N6	416-871-5600
Greengate Industrial Polymers	Ordsall Ln., Salford, Gr. Manes., England	M5 4TD	
Greening Donald Co. Ltd.	55 Queen St. N., Hamilton, Ontario	L8N 3J3	416-528-5971
Grove Manufacturing Company	Shady Grove, Pennsylvania	17256	717-597-8121
Gyro Mining Transport Ltd.	Hellaby Ind. Est., Rotherham, Yorks., England	S66 8QB	0709-547671
Hawker Siddeley Group (Dosco, Noyes)	32 Duke Street, St. Yaine's, London, England	SW1Y6DG	01-930-6177
Hepburn Ltd., John T.	911 Dupont St., Toronto, Ontario	M6H 1Z2	416-671-2200
H.K. Porter, Inc.	Porter Bldg., Pittsburg, Pennsylvania	14219	800-368-3017
Hudson Ltd. Robert	Raletrex Works, Morley, Leeds, Yorks, England	LS27 8TG	
Hunslett (Hunslett Engine Works)	Leeds, England,	LS101BT	Leeds 32261
Huwood Ltd.	Gateshead-on-Tyne, England,	NE11 0LP	
Huwood-Irwin Co.	Box 409, Irwin, Pennsylvania	15642	412-868-5000
Industrialexportimport, Foreign Trade Co.	Box 764, Bucharest, Romania	70048	
Ingersoll-Rand Mining Machinery	4201 Lee Highway, Bristol, Virginia	24201	615-968-1057
In-Pro Corp.	Route 2, Box 360A, Tazewell, Virginia	24630	703-988-6543
Isuzu Diesel North America Inc.	3707 S. State St., Salt Lake City, Utah	84115	801-262-6401
Jarvis Clark Co. Ltd.	4445 Fairview Burlington, Ontario	L7L 2A4	416-632-4940
Jeffrey Mining Mfg. (Dresser)	274 E First Ave., P.O. Box 1789, Columbus, Ohio	43216	614-297-3123

APPENDIX B-2 (Continued)
PARTIAL LIST OF MANUFACTURERS
PERSONNEL AND MATERIALS TRANSPORT EQUIPMENT
ADDRESSES

Name	Address	Postal Code	Telephone
John Deere Construction Equipment	1116 Blair Rd., Burlington, Ontario	L7M 1K9	416-335-4290
Joy Manufacturing Co.	Oliver Bldg, Pittsburgh, Pennsylvania	15222	412-562-4500
Kaelble, GmbH Carl	Postf 1320, 7150 Backnang, Fed. Rep. Germany		07191-8931
Kersey Manufacturing Co.	Box 151, Bluefield, Virginia	24605	703-326-1121
Kleber Industrie	49 Rue Jean Jaures, F-95871 Bezons Cedex, France		
Klochkner-Humboldt-Deutz AG	Postf 800 509, 5000 Koln, Fed. Rep. Germany		
Kopex, Export-Import	Dzial Raklamy, Grabowa 1, Katowice, Poland		40-952
Krampe & Co.	D-5810 Witten 3-Herbede, Fed. Rep. Germany		
Krupp GmbH Canada Inc.	Suite 405, 1177 11 Avenue S.W., Calgary, Alberta	T2R 0G5	403-245-2866
Kubota Tractor Canada Ltd.	390 Steel Case Road, Unit 2, Markham, Ontario	L3R 1G2	416-495-1090
Lake Shore Inc.	Iron Mountain, Michigan	49801	906-774-1500
Lead Industries Assoc. Inc.	292 Madison Ave., New York, New York	10017	212-578-4750
Lebus International Engineers Inc.	Box 2352, Longview, Texas	75606	214-758-5521
Long-Airdox Co., (Marmon Group)	Box 331, Oakhill, West Virginia	25901	304-469-3301
MAN (GHH) Canada Inc.	6600 Trans Canada Highway, St. Claire, Quebec	H9R 4S2	514-694-3000
Mannesman Demag Ltd.	2400 Royal Windsor Drive, Mississagua, Ontario	L5J 1K7	416-8234500
Marathon Letourneau Co.	Box 2307, Longview, Texas	75606	214-753-3449
Markham & Co. Ltd.	Broad Oaks Works, Chesterfield, England		0246-76121
Material de Fond d'Industrie	37 Paul-Doumer Ave., Paris, France		1-504-7928
McJunkin Corporation	Box 513, Charleston, West Virgina	25322	304-348-5211
Mercedes-Benz Canada Inc.	849 Eglinton Avenue East, Toronto, Ontario	M4G 2L5	416-425-3550
Michelin Tire Corp.	3300 Cote Vertu, St. Laurent, Quebec	H4R 2B8	514-337-3411
Miltor Drilling Equipment Ltd.	1360 Kelley Lake Road, Sudbury, Ontario	P3E 5P4	705-522-5841
Mine Equipment Co.	2304 Industrial Drive, Mt. Vernon, Illinois	62864	618-242-6031
Mine Safety Appliance Co.	600 Penn Center Blvd., Pittsburg, Pennsylvania	15235	412-273-5196
Minejack Mining Equipment	Box 160, Woodstock, Ontario	N4S 7X1	519-599-2015
Mines de Potasse D'Alsace	11 Avenue D'Altkirch, F-68100 Mullhouse, France		
Mining Transportation Co. AB (Kiruna)	3070 Mississauga, Ontario	L4X 2G1	416-625-1370
Monninghoff GmbH & Co. KG	Postf 10 17 49, 4630, Bochum 1, Fed Rep Germany		0234-37155
Mouty-Bonehill	16 Jean-Jaures Ave., Mouty, France		2-745-0386
Muckenhaupt GmBh Becorit	Postfach 800352, 4320 Hattingen, Fed Rep Germany		02324-3990
Mutsui Miike Machinery Col	Mitsui Bldg 2-1-T Choine Nihonbashi-2, Tokyo, Japan		
MWM Motoren-Werke Mannheim AG	D-6800 Mannheim 1, Postfach 1563, West Germany		(0621)3841
National Mine Service Co.	Goney Ave., Esterhezy, Saskatchewan	S0A 0X0	306-745-2051
Neeham Bros. and Brown Ltd.	Pontefract Road, Barnsley, England	5701TA	0226-5243
NEI Mining Equipment Ltd. (Clayton)	Eyre Street, Shefield, England,	S13GP	
Neuhaeuser GmbH & Co.	Scharnhorststr 16, D-4670, Luenen, Fed Rep Germany		
O & K Canada (Costello)	723 46 Avenue S.E., Calgary, Alberta	T2G 2A4	403-7733
Ohio Brass Co. (Ind. Products Div.)	380 N. Main Street, Mansfield, Ohio	44903	419-522-7111
Oldhan Batteries Ltd.	Denton, Manchester, England,	M34 3AT	
Pettibone Corp.	4700 W Division St., Chicago, Illinois	60651	312-772-9300
PHB Weserhuette AG	Postf 510850, D-5000 Koeln 51, Fed Rep Germany		
Pikrose & Co. Ltd. (Marmon Group)	Audenshaw, Manchester, England,	M34 5HS	0613701368
Plymouth Locomotive Works, Inc.	Bell & High Streets, Plymouth, Ohio	44805	419-687-4641
Poclain	F60330 Le Pessis-Belleville, France		4-455-3557
Precismeca Canada Ltd.	Box 306, Nisku, Alberta	T0C 2G0	403-955-2733
Qualter Hall & Co.	Johnson Street, Barnsley, Yorkshire.	S75 2B4	(0226) 5761

APPENDIX B-2 (Continued)
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PERSONNEL AND MATERIALS TRANSPORT EQUIPMENT
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Name	Address	Postal Code	Telephone
REI (Realisation Equipements Industriels)	14, Rue D'Annam, F-75020 Paris, France		797-3549
Rexnord Canada Ltd. (Nordberg)	1181 Sheppard Ave. E, Willowdale, Ontario	M2K 1C6	416-221-9361
Ruhrthaler Schwartz & Dyckerhoff KG	Postf 011260, 4330, Muelheim-Ruhr 1, Fed Rep Germany		0208-41131
Saab-Scania AB	Box 1017, S-55111, Jonkoping, Sweden		
Safetran Systems Corp.	314 Burnett Ave., Louisville, Kentucky	40217	502-634-9492
Safety Supply Canada	214 King Street East, Toronto, Ontario	M5A 1J8	416-364-3234
Samiia	Box 127, F-59506, Dovai, France		27871111
Sanford-Day (Marmon Group)	Box 1511 Knoxville, Tennessee	37901	015-525-6224
Scharf Co.	8101 Perry Highway, Pittsburgh, Pennsylvania	15237	412-367-4448
Schopf Maschinenbau GmbH	Postf 75 03 60, D-7000, Stuttgart 75, Fed Rep Germany		
Schroeder Bros. Corporation	Box 72, Nichol Ave. McKees Rocks, Pennsylvania	15136	412-771-4810
Sheepbridge Equipment Ltd.	Chesterfield, Derbyshire, England,	S41 9QD	
Siemag Transplan GmbH	Postf 1270, 5902, Netohen 1, Fed Rep Germany		02738-211
Silec DSI	69, Rue Ampere 75017, Paris, France		2672060
Societe Stephanoise de Constructions	bp 519, St. Itienne Cedex, France	42007	77-749199
Stancanada Inc. (USSR)	249 Evans Av., Toronto, Ont.	M8Z 5V2	416-252-5767
Strojexport, Foreign Trade Corp.	POB 662, 56, 113 26 Prague 1, Czechoslovakia		2131
TBA Industrial Products Limited	Box 77, Wigan, Lancashire, England,	WN2 4XQ	Wigan 59221
TDI Turbostart (Western)	Burnaby, British Columbia		604-298-2431
Teledyne Canada Mining Products	Box 130, Thornbury, Ontario	N0H 2P0	519-599-2015
Thyssen (Great Britain) Ltd.	Bynea, Llanelli, Dyfed, Wales,	SA14 9SU	
Timberland Equipment Ltd.	Box 490, Woodstock, Ontario	N4S 7Z2	519-537-6262
Toyo Kogyo Co. Ltd.	Fuchu-Cho, Aki-Gun, Hiroshima, Japan		
Toyota Industrial Sales (EMS)	828-47 St. East, Saskatoon, Saskatchewan	S7K 0X4	306-242-0636
UMM Ltd.	Box 19, Aycliffe, Co Durham, England	DL5 G05	0325-312431/8
VOEST-Alpine AG	Postf 2, A-4010, Liz 2, Austria	A-4010	
Volvo BM AB	S-63185, Eskilstuna, Sweden		
Wagner Mining Equipment Co. (RIVQUIP)	Box 20307, Portland, Oregan	97220	503-255-2863
Westinghouse Electric Corp.	Gateway Ctr., Pittsburgh, Pennsylvania	15222	416-528-8811
Wheway Watson Holdings Ltd.	101 Sutton New Rd., Erdington, Birmingham, England	D23 6RU	
Whiting Corp. Trackmobile Div.	1602 Executive Drive, LaGrange, Georgia	30240	404-884-6651
Wilderob Equipment Co.	Box 1364, North Bay, Ontario	P1B 8K4	705-474-5399
Wilson R.M. Co. Inc.	Box 6274, Wheeling, West Virginia	26003	304-232-5860
Wilson Manufacturing Co. Inc.	3053 Mt. Vernon Rd., Winfield, West Virginia	25526	304-757-7300
Wire Rope Industries Limited	5501 Transcanada Highway, Pointe Claire, Quebec	H9R 1B7	514-697-9711
Wolff Maschinenfabrik GmbH Emil	Postf 10 42 43, 4300 Essen 1, Fed Rep Germany		0201-671011

APPENDIX C

SELECTED BIBLIOGRAPHY

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